

TABLES AND INTERCOMPARISONS OF EVOLUTIONARY SEQUENCES OF MODELS FOR MASSIVE STARS

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ABSTRACT

Tables of evolutionary sequences of models for massive stars have been prepared for a variety of physical input parameters that are normally treated as “free.” These parameters include the interior convective mixing scheme, the mixing length in the outer convective envelope, the rate of stellar wind mass loss, the initial stellar mass, and the initial chemical composition. Ranges of specified initial mass and initial chemical composition are $M/M_{\odot} = 10\text{--}120$, $X_e = 0.602\text{--}0.739$, and $Z_e = 0.021\text{--}0.044$. The tables cover evolution of the star from the zero-age main sequence to either the end of core hydrogen burning or the end of core helium burning. Differences among the evolutionary tracks are illustrated here primarily in terms of the interior mixing scheme, since the amount and timing of stellar wind mass loss are still very uncertain for initial masses above $\sim 30 M_{\odot}$.

Subject headings: stars: evolution — stars: interiors — stars: massive — stars: mass loss

1. INTRODUCTION

Evolutionary sequences of models for massive stars are very sensitive to existing uncertainties in initial chemical composition, amount of interior convective mixing, mixing length in the outer convective envelope, and rate of mass loss. These four critical parameters are, therefore, normally treated as “free.” Parameters like the equation of state, opacities, and nuclear reaction rates, as well as computational criteria like mass zoning and time steps, possess degrees of freedom that introduce much less uncertainty into the stellar models. Two qualifications, however, should be made. First, the standard Los Alamos opacities may still need improvement, even though Carson’s large corrections to the high-temperature metals contribution have turned out to be incorrect (Carson *et al.* 1984). Second, the different versions of the Los Alamos opacities and the varying computational details used by authors to construct models of massive stars introduce small, but nonnegligible, differences among the models calculated with ostensibly the same “free” parameters (de Loore 1988).

Since de Loore’s (1988) comparison of main-sequence stellar models was based on a very heterogeneous set of models, his work serves a rather different purpose from a compilation that would be based on a fully homogeneous set of models. Accordingly, a need exists for tables of fully consistent evolutionary model sequences that occupy a large grid covering the widest plausible ranges of the “free” input parameters. Various authors have published tables for massive stars that address specific aspects of this need, though on a limited scale. The most extensive studies pertaining to main-sequence evolution have varied only the rate of mass loss and the amount of overshooting from the convective core. Relatively untreated are variations of semiconvective mixing outside the convective core.

To cover systematically all these areas and to include a different functional representation of the rate of mass loss,

we present in this paper extensive tables of models for the main-sequence and post-main-sequence phases of evolution in Population I stars with initial masses in the range 10–120 M_{\odot} . On past occasions, we have received requests specifically for such numerical data, and therefore the present tables ought to prove quite useful for doing comparative theoretical studies as well as for doing semiempirical studies of the evolution of stars, star clusters, and the Galaxy. Since the post-main-sequence stages of evolution in massive stars are extremely sensitive to the “free” input parameters, even to the extent of being almost unconstrained at the present time (Stothers and Chin 1980), there seems currently to be little point in presenting tables for more than a representative sample of post-main-sequence tracks, which will illustrate the wide range of possible trajectories on the theoretical H-R diagram.

II. DESCRIPTION OF THE TABLES

The evolutionary tracks presented here are indexed in Table 1. This table lists the following parameters that identify the tracks:

Column (1) lists the table number in which the individual models appear.

Column (2) lists the mixing scheme: L or S for semiconvective mixing according to the Ledoux or Schwarzschild criterion, with no overshooting from the convective core; O for overshooting from the convective core, with no semiconvective mixing outside the convective core.

Column (3) lists d/H_P , the ratio of the overshoot distance beyond the classical Schwarzschild convective core boundary, d , to the local pressure scale height, H_P .

Column (4) lists k_{11} , the numerical coefficient in the expression for the rate of stellar-wind mass loss,

$$-dM/dt = (k_{11} \times 10^{-11}) LR / M, \quad (1)$$

TABLE 1
SUMMARY OF THE TABLES OF EVOLUTIONARY SEQUENCES

Table (1)	Mixing Scheme (2)	d/H_P (3)	k_{11} (4)	X_e (5)	Z_e (6)	α (7)	M_i/M_\odot (8)	Phase (9)	Date (10)
2	L	0	0	0.739	0.021	...	10, 15, 30, 60, 120	MS	1975, 1979
3	L	0	0	0.739	0.044	...	10, 15, 30, 60, 120	MS	1975, 1990
4	L	0	0	0.602	0.021	...	10, 15, 30, 60, 120	MS	1975, 1990
5	L	0	0	0.602	0.044	...	10, 15, 30, 60, 120	MS	1975, 1990
6	S	0	0	0.739	0.021	...	10, 15, 30, 60, 120	MS	1976, 1979
7	S	0	0	0.739	0.044	...	10, 15, 30, 60, 120	MS	1976, 1990
8	S	0	0	0.602	0.021	...	10, 15, 30, 60, 120	MS	1976, 1990
9	S	0	0	0.602	0.044	...	10, 15, 30, 60, 120	MS	1976, 1990
10	S	0	1	0.739	0.021	...	10, 15, 30, 60, 120	MS	1979, 1990
11	S	0	3	0.739	0.021	...	10, 15, 30, 60, 120	MS	1979, 1990
12	O	0.35	0	0.739	0.021	...	10, 15, 30, 60, 120	MS	1985, 1990
13	O	0.70	0	0.739	0.021	...	10, 15, 30, 60, 120	MS	1985, 1990
14	O	0.70	1	0.739	0.021	...	10, 15, 30, 60, 120	MS	1985, 1990
15	O	0.70	3	0.739	0.021	...	10, 15, 30, 60, 120	MS	1985, 1990
16A-16C.....	L	0	0	0.739	0.021	ρ	10, 15, 30	PMS	1975
17A-17E.....	L	0	0	0.739	0.021	P	10, 15, 30, 60, 120	PMS	1979, 1990
18A-18B.....	L	0	1 ^a	0.739	0.021	P	15, 30	PMS	1979
19	L	0	100 ^b	0.739	0.021	P	30	PMS	1979
20A-20D	S	0	0	0.739	0.021	ρ	10, 15, 30, 60	PMS	1976
21	S	0	0	0.739	0.021	P	120	PMS	1979
22A-22C.....	S	0	1	0.739	0.021	P	15, 30, 60	PMS	1979

NOTE.—Date refers to the year of publication.

^aMass loss only for $\log T_e < 3.85$.

^bMass loss only for $\log T_e < 3.70$.

where L , R , and M are in solar units and dM/dt is in solar masses per year.

Column (5) lists X_e , the initial abundance of hydrogen by mass.

Column (6) lists Z_e , the initial abundance of metals by mass.

Column (7) lists the classification of α , the ratio of convective mixing length to the local scale height (in the outer convective envelope), where ρ refers to the density scale height and P refers to the pressure scale height.

Column (8) lists M_i/M_\odot , the initial mass of the star in solar units.

Column (9) lists the evolutionary phase: MS for main sequence (up to the end of central hydrogen burning) and PMS for post-main sequence (up to the end of central helium burning).

Column (10) lists the year of first publication of the evolutionary track in a graphical format (usually the H-R diagram).

Otherwise, all the tracks were calculated with the same input physics, including the same Cox-Stewart opacities. The basic computer program and the associated physical subroutines have been described elsewhere (Stothers and Chin 1973a). The assumed dependences of the rate of mass loss on L , R , and M were adopted from McCrea (1962), but they agree sufficiently well (within the prevailing observational uncertainties) with those recommended by Lamers (1981) for hot stars, Kudritzki and Reimers (1978) for cool stars, and Waldron (1984) as well as de Jager, Nieuwenhuijzen, and van der Hucht (1988) for stars of all effective temperatures.

The total number of tracks tabulated in this paper is 70 for the main sequence and 19 for the post-main sequence. Most

of these tracks have been displayed on the H-R diagram in four previously published papers (Stothers and Chin 1975, 1976, 1979, 1985). To complete the present grid, 15 new main-sequence tracks and one new post-main-sequence track have been computed; the latter track (listed in Table 17A) is displayed below in Figure 5. The specified initial stellar masses are 10, 15, 30, 60, and $120 M_\odot$. The ranges of other specified parameters are $d/H_P = 0-0.7$, $k_{11} = 0-3$, $X_e = 0.602-0.739$, $Z_e = 0.021-0.044$, $\alpha_\rho = 0.4$, and $\alpha_P = 1$.

Tables 2 through 22C present selected models from the evolutionary tracks. Units of density and temperature are g cm^{-3} and K, respectively. Stellar mass fraction is represented by q , with q_{core} , q_{shell} , and q_{env} indicating the convective core boundary, hydrogen-burning shell peak, and inner boundary of the outer convective envelope, respectively. Only in the case of $q_{\text{env}} < 0.9$ is q_{env} explicitly tabulated. For six post-main-sequence tracks, listed in Tables 17A, 17B, 17C, 18A, 18B, and 19, the first model tabulated differs slightly from its counterpart in Tables 16A, 16B, and 16C, because in each of these six cases the post-main-sequence track was recomputed from the zero-age main sequence with slightly different mass zoning and time steps. Stellar models at important turning points on the H-R diagram are included with enough other models so that the whole track can be plotted easily.

In the present tables, we have omitted evolutionary tracks of models that do not include semiconvective mixing or overshooting beyond the Schwarzschild convective core, because such tracks are physically less realistic than the ones tabulated here (Stothers and Chin 1973a). Similarly, tracks based on completely suppressed core convection are omitted, although tables of models for such tracks have been pub-

TABLE 2

CASE I, $d/H_P = 0$, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	X_c	q_{core}
10.....	0.00	3.734	4.412	7.492	0.967	0.739	0.315
	13.56	3.890	4.388	7.524	0.986	0.405	0.218
	18.18	3.957	4.363	7.548	1.037	0.202	0.172
	19.88	3.991	4.345	7.569	1.096	0.097	0.150
	20.83	4.016	4.336	7.601	1.194	0.026	0.130
	21.09	4.037	4.351	7.648	1.341	0.004	0.117
15.....	0.00	4.262	4.492	7.524	0.782	0.739	0.387
	7.59	4.431	4.468	7.557	0.804	0.402	0.282
	10.22	4.514	4.435	7.585	0.868	0.194	0.225
	11.00	4.542	4.419	7.604	0.920	0.111	0.200
	11.60	4.568	4.408	7.636	1.020	0.035	0.183
	11.82	4.588	4.426	7.696	1.203	0.004	0.166
30.....	0.00	5.046	4.604	7.570	0.526	0.739	0.546
	3.60	5.210	4.575	7.601	0.555	0.399	0.421
	4.84	5.281	4.537	7.627	0.615	0.206	0.345
	5.36	5.314	4.509	7.650	0.684	0.100	0.312
	5.66	5.337	4.491	7.688	0.804	0.026	0.284
	5.74	5.348	4.503	7.737	0.954	0.004	0.274
60.....	0.00	5.686	4.682	7.605	0.327	0.739	0.709
	2.24	5.811	4.646	7.631	0.359	0.404	0.561
	3.07	5.868	4.600	7.654	0.416	0.207	0.467
	3.40	5.893	4.567	7.672	0.472	0.109	0.425
	3.68	5.922	4.525	7.732	0.661	0.012	0.381
	3.70	5.927	4.530	7.754	0.758	0.004	0.375
120.....	0.00	6.214	4.728	7.631	0.161	0.739	0.831
	1.64	6.303	4.688	7.655	0.199	0.405	0.647
	2.31	6.345	4.630	7.676	0.260	0.210	0.551
	2.63	6.366	4.579	7.698	0.333	0.093	0.498
	2.84	6.384	4.520	7.760	0.533	0.009	0.446
	2.85	6.386	4.522	7.784	0.607	0.004	0.444

TABLE 3

CASE I, $d/H_P = 0$, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.044$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	X_c	q_{core}
10.....	0.00	3.734	4.412	7.492	0.967	0.739	0.315
	15.....	0.00	15.31	3.796	4.343	7.502	0.939
	20.60	20.60	3.857	4.318	7.524	0.991	0.158
	22.59	22.59	3.887	4.299	7.545	1.052	0.094
	23.56	23.56	3.909	4.289	7.572	1.136	0.138
	23.95	23.95	3.939	4.306	7.628	1.312	0.004
15.....	0.00	4.202	4.457	7.504	4.741	0.725	0.739
	8.09	4.367	4.430	7.536	7.553	0.403	0.268
	10.98	4.445	4.396	7.563	0.819	0.194	0.211
	12.03	4.479	4.373	7.588	0.892	0.090	0.182
	12.49	4.498	4.365	7.614	0.973	0.036	0.168
	12.74	4.521	4.383	7.672	1.155	0.004	0.154
30.....	0.00	5.014	4.577	7.550	0.469	0.739	0.523
	3.73	5.175	4.544	7.581	0.500	0.399	0.402
	5.02	5.244	4.502	7.606	0.562	0.206	0.332
	5.56	5.277	4.471	7.629	0.632	0.101	0.301
	5.90	5.302	4.450	7.673	0.770	0.021	0.273
	5.97	5.311	4.457	7.706	0.872	0.004	0.268
60.....	0.00	5.665	4.659	7.586	0.269	0.739	0.689
	2.28	5.788	4.620	7.611	0.301	0.408	0.542
	3.21	5.851	4.563	7.636	0.367	0.193	0.456
	3.54	5.874	4.523	7.656	0.430	0.094	0.408
	3.78	5.898	4.478	7.709	0.601	0.013	0.368
	3.80	5.904	4.483	7.741	0.697	0.004	0.366
120.....	0.00	6.198	4.707	7.613	0.103	0.739	0.813
	1.66	6.292	4.657	7.637	0.144	0.394	0.633
	2.29	6.332	4.594	7.658	0.205	0.200	0.539
	2.55	6.350	4.538	7.676	0.266	0.102	0.491
	2.78	6.371	4.461	7.752	0.508	0.006	0.442

TABLE 4

CASE L, $d/H_p = 0$, $k_{11} = 0$, $X_e = 0.602$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	X_c	q_{core}
10.....	0.00	3.957	4.463	7.514	0.924	0.602	0.348
	7.18	4.097	4.446	7.541	0.934	0.352	0.260
10.25	4.178	4.422	7.569	0.995	0.175	0.214	10.....
11.13	4.201	4.413	7.581	1.027	0.107	0.200	10.79
12.02	4.236	4.404	7.615	1.126	0.026	0.175	12.37
12.22	4.258	4.419	7.663	1.272	0.004	0.160	13.26
15.....	0.00	4.461	4.539	7.544	0.754	0.602	0.430
	3.52	4.578	4.526	7.565	0.765	0.404	0.357
5.75	4.674	4.500	7.592	0.813	0.209	0.294	15.....
6.62	4.719	4.481	7.616	0.875	0.103	0.258	6.22
7.09	4.748	4.472	7.648	0.970	0.034	0.240	7.14
7.27	4.767	4.488	7.702	1.135	0.004	0.222	7.56
30.....	0.00	5.199	4.641	7.586	0.519	0.602	0.597
	1.83	5.308	4.625	7.607	0.536	0.400	0.503
3.01	5.391	4.592	7.632	0.588	0.206	0.421	3.11
3.49	5.430	4.565	7.656	0.653	0.101	0.377	3.61
3.78	5.456	4.550	7.694	0.770	0.026	0.348	3.91
3.85	5.467	4.563	7.743	0.919	0.004	0.335	3.99
60.....	0.00	5.801	4.710	7.619	0.333	0.602	0.750
	1.22	5.880	4.689	7.635	0.352	0.399	0.641
2.02	5.945	4.648	7.659	0.404	0.202	0.541	60.....
2.34	5.973	4.618	7.678	0.458	0.105	0.498	2.07
2.59	6.001	4.583	7.730	0.621	0.015	0.441	2.39
2.61	6.008	4.591	7.770	0.742	0.004	0.435	2.63
120.....	0.00	6.301	4.749	7.644	0.174	0.602	0.856
	0.92	6.359	4.723	7.658	0.196	0.409	0.737
1.53	6.406	4.675	7.682	0.256	0.194	0.623	0.86
1.79	6.426	4.635	7.701	0.314	0.097	0.562	1.56
1.98	6.447	4.585	7.763	0.508	0.010	0.506	1.81
1.99	6.449	4.587	7.787	0.582	0.004	0.504	2.01

TABLE 5

CASE L, $d/H_p = 0$, $k_{11} = 0$, $X_e = 0.602$, $Z_e = 0.044$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	X_c	q_{core}
10.....	0.00	3.881	4.423	7.493	0.867	0.602	0.316
	7.18	3.995	4.408	7.515	0.883	0.393	0.263
10.25	4.178	4.073	4.387	7.537	0.926	0.204	0.212
11.13	4.201	4.027	4.115	4.369	0.982	0.099	0.184
12.02	4.236	4.044	4.146	4.360	0.790	1.077	0.027
12.22	4.258	4.064	4.172	4.375	7.638	1.223	0.004
15.....	0.00	4.409	4.505	7.524	0.696	0.602	0.401
	3.52	4.520	4.492	7.544	0.710	0.410	0.338
5.75	4.674	4.621	4.461	7.573	0.765	0.201	0.272
6.62	4.719	4.665	4.440	7.596	0.831	0.096	0.245
7.09	4.748	4.689	4.430	7.623	0.911	0.038	0.225
7.27	4.767	4.713	4.448	7.683	1.092	0.004	0.209
30.....	0.00	5.170	4.612	7.567	0.461	0.602	0.574
	1.83	5.279	4.595	7.587	0.480	0.400	0.488
3.01	5.363	4.536	4.558	7.612	0.533	0.207	0.409
3.49	5.400	4.529	4.529	7.635	0.598	0.101	0.366
3.78	5.427	4.510	4.510	7.673	0.715	0.027	0.336
3.85	5.435	4.522	4.522	7.722	0.862	0.004	0.329
60.....	0.00	5.781	4.686	7.599	0.275	0.602	0.730
	1.22	5.861	4.662	7.616	0.295	0.395	0.624
2.02	5.945	4.641	4.616	7.639	0.349	0.199	0.527
2.34	5.973	4.618	4.582	7.658	0.405	0.101	0.487
2.59	6.001	4.583	4.581	7.711	0.568	0.014	0.437
2.61	6.008	4.591	4.587	7.743	0.665	0.004	0.426
120.....	0.00	6.285	4.727	7.624	0.115	0.602	0.838
	0.92	6.340	4.703	7.638	0.138	0.407	0.722
1.53	6.391	4.641	4.641	7.662	0.199	0.192	0.602
1.79	6.426	4.635	4.599	7.681	0.258	0.094	0.549
1.98	6.447	4.585	4.534	7.751	0.476	0.007	0.497
1.99	6.449	4.587	4.535	7.766	0.526	0.004	0.491

TABLE 6
CASE S, $d/H_P = 0$, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	X_e	q_{core}
10	0.00	3.734	4.412	7.492	0.967	0.739	0.315
	13.72	3.893	4.388	7.525	0.987	0.404	0.217
18.23	3.965	4.360	7.551	1.044	0.205	0.171	
19.95	3.998	4.343	7.574	1.109	0.101	0.145	
20.78	4.017	4.337	7.600	1.189	0.040	0.131	
21.21	4.041	4.356	7.658	1.371	0.004	0.114	
15	0.00	4.262	4.492	7.524	0.782	0.739	0.387
	7.76	4.433	4.468	7.557	0.806	0.404	0.240
10.37	4.514	4.436	7.585	0.867	0.194	0.224	
11.15	4.542	4.419	7.603	0.920	0.111	0.199	
11.74	4.568	4.408	7.636	1.020	0.035	0.183	
11.97	4.588	4.426	7.695	1.203	0.004	0.165	
30	0.00	5.046	4.604	7.570	0.526	0.739	0.546
	3.75	5.220	4.575	7.602	0.553	0.400	0.424
5.11	5.303	4.535	7.627	0.610	0.207	0.361	
5.67	5.342	4.504	7.651	0.678	0.101	0.324	
6.00	5.367	4.486	7.689	0.796	0.026	0.297	
6.08	5.378	4.494	7.730	0.920	0.004	0.290	
60	0.00	5.686	4.682	7.605	0.327	0.739	0.709
	2.30	5.829	4.644	7.634	0.364	0.396	0.553
3.18	5.896	4.590	7.659	0.427	0.200	0.475	
3.53	5.924	4.551	7.681	0.491	0.102	0.433	
3.78	5.947	4.519	7.729	0.640	0.019	0.394	
3.81	5.953	4.527	7.769	0.763	0.004	0.394	
120	0.00	6.214	4.728	7.631	0.161	0.739	0.831
	1.69	6.310	4.685	7.655	0.201	0.398	0.652
2.41	6.360	4.622	7.679	0.266	0.193	0.555	
2.68	6.378	4.575	7.697	0.324	0.099	0.510	
2.89	6.398	4.520	7.756	0.512	0.011	0.459	
2.91	6.401	4.524	7.788	0.611	0.004	0.456	
2.92	6.413	4.567	7.918	1.008	0.0	0.426	
2.92	6.427	4.430	7.712	0.374	0.076 ^a	0.542	
3.04	6.435	4.370	7.736	0.449	0.025	0.520	
3.10	6.444	4.323	7.809	0.674	0.002	0.504	

^aMerger of intermediate fully convective zone with convective core leads to a renewed phase of core hydrogen burning (not calculated for other initial chemical compositions at this mass).

TABLE 7

CASE S, $d/H_P = 0$, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.044$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	X_c	q_{core}
10	0.00	10	0.00	3.646	4.369	7.471	0.910
	15	15	15	3.806	4.343	7.503	0.937
	20	20	20	3.880	4.312	7.529	0.997
	22	22	22	3.914	4.292	7.551	1.060
	23	23	23	3.939	4.281	7.581	1.153
	23	23	23	3.966	4.299	7.633	1.316
	23	23	23	3.996	4.299	7.633	0.005
	23	23	23	4.005	4.299	7.633	0.115
	23	23	23	4.005	4.299	7.633	0.223
	23	23	23	4.005	4.299	7.633	0.401
	23	23	23	4.005	4.299	7.633	0.205
	23	23	23	4.005	4.299	7.633	0.159
	23	23	23	4.005	4.299	7.633	0.104
	23	23	23	4.005	4.299	7.633	0.139
	23	23	23	4.005	4.299	7.633	0.128
	23	23	23	4.005	4.299	7.633	0.115
	23	23	23	4.005	4.299	7.633	0.267
	23	23	23	4.005	4.299	7.633	0.202
	23	23	23	4.005	4.299	7.633	0.217
	23	23	23	4.005	4.299	7.633	0.358
	23	23	23	4.005	4.299	7.633	0.267
	23	23	23	4.005	4.299	7.633	0.202
	23	23	23	4.005	4.299	7.633	0.195
	23	23	23	4.005	4.299	7.633	0.026
	23	23	23	4.005	4.299	7.633	0.176
	23	23	23	4.005	4.299	7.633	0.005
	23	23	23	4.005	4.299	7.633	0.171

TABLE 8

CASE S, $d/H_P = 0$, $k_{11} = 0$, $X_e = 0.602$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	X_c	q_{core}
10.....	0.00	3.957	4.463	7.514	0.924	0.602	0.348
6.35	4.079	4.449	7.537	0.935	0.390	0.277	10.....
10.04	4.172	4.425	7.566	0.987	0.191	0.217	11.04
11.15	4.207	4.412	7.585	1.037	0.108	0.198	12.29
11.88	4.234	4.405	7.611	1.115	0.043	0.176	13.11
12.25	4.260	4.423	7.670	1.296	0.004	0.158	13.55
15.....	0.00	4.461	4.539	7.544	0.754	0.602	0.430
3.46	4.576	4.527	7.564	0.765	0.410	0.360	15.....
6.05	4.690	4.497	7.596	0.820	0.191	0.288	6.25
6.75	4.727	4.481	7.615	0.870	0.107	0.261	7.16
7.70	4.758	4.471	7.647	0.962	0.036	0.243	7.69
7.88	4.779	4.489	7.707	1.145	0.004	0.225	7.89
30.....	0.00	5.199	4.641	7.586	0.519	0.602	0.597
1.87	5.313	4.625	7.607	0.536	0.401	0.510	30.....
3.16	5.409	4.591	7.633	0.585	0.208	0.438	1.90
3.69	5.456	4.562	7.657	0.647	0.102	0.397	3.27
4.01	5.487	4.543	7.695	0.761	0.027	0.366	3.73
4.10	5.498	4.557	7.746	0.913	0.004	0.355	4.11
60.....	0.00	5.801	4.710	7.619	0.333	0.602	0.750
1.23	5.893	4.688	7.638	0.357	0.392	0.634	60.....
2.08	5.967	4.642	7.664	0.415	0.197	0.544	1.26
2.42	5.999	4.606	7.686	0.478	0.098	0.498	2.11
2.65	6.023	4.579	7.734	0.625	0.018	0.457	2.38
2.68	6.029	4.589	7.775	0.747	0.004	0.452	2.66
120.....	0.00	6.301	4.749	7.644	0.174	0.602	0.856
0.84	6.356	4.726	7.658	0.196	0.407	0.737	120.....
1.53	6.411	4.677	7.682	0.253	0.199	0.625	0.93
1.79	6.432	4.631	7.699	0.307	0.104	0.573	1.56
2.00	6.453	4.578	7.758	0.489	0.012	0.521	1.81
2.01	6.457	4.583	7.790	0.587	0.004	0.506	2.03

TABLE 9

CASE S, $d/H_P = 0$, $k_{11} = 0$, $X_e = 0.602$, $Z_e = 0.044$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	X_c	q_{core}
10.....	0.00	3.881	4.423	7.493	0.867	0.602	0.316
6.35	4.079	4.449	7.537	0.935	0.277	0.408	7.515
10.04	4.172	4.425	7.566	0.987	0.191	0.088	7.543
11.15	4.207	4.412	7.585	1.037	0.108	0.039	7.638
11.88	4.234	4.405	7.611	1.115	0.043	0.090	7.662
12.25	4.260	4.423	7.670	1.296	0.004	0.043	7.588
15.....	0.00	4.409	4.505	7.524	0.696	0.602	0.401
3.46	4.576	4.527	7.564	0.765	0.410	0.492	7.544
6.05	4.690	4.497	7.596	0.820	0.191	0.672	7.572
6.75	4.727	4.481	7.615	0.870	0.107	0.442	7.593
7.70	4.758	4.471	7.647	0.962	0.036	0.431	7.625
7.88	4.779	4.489	7.707	1.145	0.004	0.225	7.685
30.....	0.00	5.170	4.612	7.567	0.461	0.602	0.574
1.87	5.313	4.625	7.607	0.536	0.401	0.496	7.585
3.16	5.409	4.591	7.633	0.585	0.208	0.571	7.611
3.69	5.456	4.562	7.657	0.647	0.102	0.409	7.629
4.01	5.487	4.543	7.695	0.761	0.027	0.349	7.677
4.10	5.498	4.557	7.746	0.913	0.004	0.339	7.721
60.....	0.00	5.781	4.686	7.599	0.275	0.602	0.730
1.23	5.893	4.688	7.638	0.357	0.392	0.634	7.618
2.08	5.967	4.642	7.664	0.415	0.197	0.544	5.943
2.42	5.999	4.606	7.686	0.478	0.098	0.498	6.610
2.65	6.023	4.579	7.734	0.625	0.018	0.457	5.967
2.68	6.029	4.589	7.775	0.747	0.004	0.452	6.003
120.....	0.00	6.285	4.727	7.624	0.115	0.602	0.838
0.84	6.356	4.726	7.658	0.196	0.407	0.711	7.640
1.53	6.411	4.677	7.682	0.253	0.199	0.625	7.663
1.79	6.432	4.631	7.699	0.307	0.104	0.573	7.713
2.00	6.453	4.578	7.758	0.489	0.012	0.521	6.435
2.01	6.457	4.583	7.790	0.587	0.004	0.506	6.444

TABLE 10
CASE S, $d/H_P = 0$, $k_{11} = 1$, $X_e = 0.739$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	X_c	q_{core}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
10	0.00	3.734	4.412	0.739	7.492	0.967	0.739	0.315	2.1(-8)
9.62	14.22	3.843	4.379	0.739	7.520	1.000	0.399	0.227	3.5(-8)
9.42	19.07	3.895	4.347	0.739	7.545	1.061	0.200	0.170	5.0(-8)
9.32	20.88	3.916	4.327	0.739	7.564	1.120	0.101	0.153	6.0(-8)
9.24	22.07	3.937	4.315	0.739	7.600	1.234	0.025	0.131	6.9(-8)
9.22	22.34	3.955	4.328	0.739	7.644	1.375	0.004	0.116	6.9(-8)
15	0.00	4.262	4.492	0.739	7.524	0.782	0.739	0.387	5.8(-8)
14.4.....	7.81	4.385	4.460	0.739	7.553	0.816	0.396	0.286	1.0(-7)
14.1.....	10.45	4.445	4.426	0.739	7.578	0.877	0.199	0.234	1.6(-7)
13.9.....	11.45	4.471	4.403	0.739	7.597	0.937	0.101	0.208	1.9(-7)
13.8.....	12.16	4.499	4.385	0.739	7.640	1.072	0.018	0.177	2.3(-7)
13.7.....	12.26	4.511	4.397	0.739	7.680	1.196	0.004	0.172	2.3(-7)
30	0.00	5.046	4.604	0.739	7.570	0.526	0.739	0.546	2.6(-7)
28.8.....	3.64	5.171	4.571	0.739	7.597	0.561	0.407	0.431	4.8(-7)
28.0.....	4.96	5.235	4.529	0.739	7.621	0.620	0.210	0.366	7.5(-7)
27.6.....	5.47	5.263	4.499	0.739	7.639	0.677	0.112	0.330	9.6(-7)
27.1.....	5.88	5.295	4.461	0.739	7.690	0.839	0.016	0.298	1.3(-6)
27.1.....	5.93	5.304	4.469	0.739	7.730	0.960	0.004	0.286	1.3(-6)
60	0.00	5.686	4.682	0.739	7.605	0.327	0.739	0.709	8.3(-7)
57.6.....	2.24	5.791	4.642	0.739	7.631	0.369	0.399	0.558	1.5(-6)
56.1.....	3.08	5.842	4.590	0.739	7.653	0.431	0.204	0.484	2.3(-6)
55.3.....	3.42	5.865	4.549	0.739	7.672	0.490	0.106	0.441	3.0(-6)
54.3.....	3.70	5.893	4.491	0.739	7.740	0.705	0.009	0.399	4.5(-6)
54.2.....	3.72	5.895	4.497	0.739	7.764	0.779	0.004	0.393	4.4(-6)
120	0.00	6.214	4.728	0.739	7.631	0.161	0.739	0.831	2.1(-6)
115.9.....	1.62	6.289	4.685	0.739	7.653	0.205	0.411	0.663	3.3(-6)
113.0.....	2.33	6.330	4.614	0.739	7.676	0.274	0.208	0.568	5.5(-6)
111.2.....	2.62	6.348	4.552	0.739	7.696	0.342	0.106	0.525	7.9(-6)
108.7.....	2.87	6.368	4.466	0.739	7.769	0.575	0.006	0.477	1.3(-5)

TABLE 11
CASE S, $d/H_P = 0$, $k_{11} = 3$, $X_e = 0.739$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	X_c	q_{core}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
10	0.00	3.734	4.412	0.739	7.492	0.967	0.739	0.315	6.1(-8)
8.90	15.03	3.753	4.362	0.739	7.515	1.035	0.396	0.219	8.9(-8)
8.32	20.56	3.756	4.318	0.739	7.537	1.116	0.197	0.164	1.2(-7)
8.06	22.55	3.754	4.294	0.739	7.553	1.177	0.109	0.148	1.4(-7)
7.82	24.17	3.757	4.274	0.739	7.593	1.313	0.021	0.124	1.6(-7)
7.78	24.45	3.772	4.287	0.739	7.637	1.452	0.004	0.110	1.6(-7)
15	0.00	4.262	4.492	0.739	7.524	0.782	0.739	0.387	1.8(-7)
13.3.....	7.74	4.305	4.446	0.739	7.548	0.844	0.398	0.280	2.7(-7)
12.3.....	11.06	4.324	4.401	0.739	7.570	0.920	0.202	0.232	3.8(-7)
11.8.....	12.30	4.333	4.367	0.739	7.590	0.993	0.097	0.199	4.8(-7)
11.4.....	13.06	4.342	4.340	0.739	7.631	1.128	0.019	0.176	5.9(-7)
11.3.....	13.19	4.353	4.351	0.739	7.676	1.270	0.003	0.170	6.0(-7)
30	0.00	5.046	4.604	0.739	7.570	0.526	0.739	0.546	7.8(-7)
26.4.....	3.70	5.105	4.561	0.739	7.593	0.584	0.408	0.429	1.3(-6)
24.1.....	5.16	5.140	4.507	0.739	7.616	0.660	0.209	0.374	2.0(-6)
22.7.....	5.75	5.158	4.460	0.739	7.637	0.731	0.106	0.342	2.8(-6)
21.1.....	6.22	5.180	4.406	0.739	7.701	0.940	0.009	0.317	4.3(-6)
21.0.....	6.24	5.184	4.410	0.739	7.725	1.012	0.004	0.315	4.4(-6)
60	0.00	5.686	4.682	0.739	7.605	0.327	0.739	0.709	2.5(-6)
52.9.....	2.29	5.748	4.634	0.739	7.629	0.388	0.397	0.577	4.1(-6)
48.2.....	3.17	5.785	4.659	0.739	7.651	0.463	0.203	0.513	6.9(-6)
45.3.....	3.51	5.803	4.516	0.739	7.671	0.528	0.108	0.494	1.0(-5)
41.7.....	3.80	5.823	4.461	0.712	7.718	0.683	0.017	0.484	1.5(-5)
41.2.....	3.84	5.829	4.470	0.694	7.758	0.805	0.004	0.472	1.6(-5)
120	0.00	6.214	4.728	0.739	7.631	0.161	0.739	0.831	6.1(-6)
107.1.....	1.69	6.261	4.679	0.739	7.651	0.218	0.399	0.683	9.6(-6)
98.1.....	2.39	6.294	4.608	0.712	7.676	0.301	0.205	0.619	1.7(-5)
92.0.....	2.69	6.310	4.563	0.662	7.696	0.374	0.102	0.598	2.3(-5)
85.4.....	2.93	6.325	4.534	0.582	7.752	0.554	0.011	0.580	3.1(-5)
84.9.....	2.95	6.328	4.539	0.577	7.775	0.624	0.004	0.577	3.1(-5)

TABLE 12

CASE O, $d/H_p = 0.35$, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log \rho_e$	X_e	q_{core}	M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log \rho_e$	X_e	q_{core}		
10.....	0.00	3.733	4.409	7.492	0.964	0.739	0.404	10.....	0.00	3.715	4.407	7.492	0.954	0.739	0.481
	17.72	3.950	4.388	7.527	0.965	0.398	0.330		20.93	3.998	4.390	7.532	0.942	0.402	0.413
23.27	4.070	4.352	7.555	1.006	0.199	0.272		27.04	4.151	4.352	7.560	0.975	0.208	0.361	
25.20	4.127	4.323	7.577	1.060	0.099	0.245		29.47	4.229	4.314	7.582	1.020	0.103	0.327	
26.44	4.176	4.297	7.622	1.185	0.019	0.212		30.94	4.313	4.264	7.646	1.193	0.010	0.289	
26.61	4.191	4.304	7.653	1.278	0.006	0.206		31.02	4.323	4.270	7.669	1.261	0.004	0.285	
15.....	0.00	4.260	4.490	7.524	0.780	0.739	0.478	15.....	0.00	4.245	4.488	7.524	0.773	0.739	0.541
	9.38	4.477	4.469	7.558	0.786	0.398	0.390		10.88	4.510	4.472	7.560	0.769	0.398	0.477
12.35	4.599	4.430	7.586	0.833	0.199	0.336		14.22	4.665	4.430	7.590	0.807	0.199	0.424	
13.43	4.655	4.398	7.608	0.886	0.100	0.306		15.37	4.741	4.387	7.613	0.859	0.099	0.395	
14.20	4.717	4.360	7.671	1.073	0.010	0.275		16.17	4.824	4.319	7.677	1.042	0.010	0.362	
14.24	4.725	4.366	7.694	1.142	0.004	0.270		16.22	4.832	4.323	7.700	1.112	0.004	0.358	
30.....	0.00	5.044	4.601	7.570	0.525	0.739	0.618	30.....	0.00	5.035	4.601	7.569	0.522	0.739	0.669
	4.18	5.243	4.575	7.602	0.545	0.393	0.527		4.61	5.264	4.578	7.603	0.537	0.394	0.607
5.59	5.347	4.525	7.629	0.599	0.196	0.464		6.15	5.394	4.519	7.631	0.588	0.197	0.556	
6.13	5.397	4.477	7.650	0.659	0.098	0.433		6.71	5.454	4.457	7.652	0.644	0.099	0.524	
6.53	5.451	4.407	7.721	0.876	0.007	0.394		7.16	5.529	4.322	7.746	0.924	0.004	0.484	
60.....	0.00	5.685	4.680	7.605	0.327	0.739	0.759	60.....	0.00	5.680	4.680	7.605	0.325	0.739	0.793
	2.37	5.837	4.632	7.632	0.357	0.406	0.653		2.54	5.833	4.647	7.634	0.354	0.404	0.720
3.29	5.920	4.579	7.657	0.413	0.211	0.584		3.51	5.951	4.568	7.659	0.408	0.208	0.662	
3.68	5.964	4.500	7.679	0.480	0.103	0.542		3.92	6.009	4.445	7.683	0.479	0.101	0.621	
3.99	6.012	4.340	7.785	0.809	0.002	0.493		4.20	6.060	4.014	7.740	0.659	0.015	0.590	
120.....	0.00	6.213	4.729	7.631	0.161	0.739	0.862	120.....	0.00	6.210	4.729	7.631	0.160	0.739	0.883
	1.74	6.327	4.679	7.656	0.200	0.404	0.736		1.81	6.339	4.679	7.657	0.199	0.405	0.794
2.45	6.388	4.583	7.678	0.262	0.209	0.659		2.59	6.419	4.541	7.682	0.266	0.199	0.724	
2.77	6.425	4.438	7.701	0.339	0.105	0.613		2.90	6.467	4.127	7.706	0.346	0.100	0.689	
2.98	6.452	4.043	7.742	0.476	0.027	0.579		2.97	6.479	3.664	7.716	0.375	0.077	0.619	
3.03	6.456	3.595	7.781	0.596	0.007	0.568									

TABLE 13

CASE O, $d/H_p = 0.70$, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log \rho_e$	X_e	q_{core}	M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log \rho_e$	X_e	q_{core}		
10.....	0.00	3.733	4.409	7.492	0.964	0.739	0.404	10.....	0.00	3.715	4.407	7.492	0.954	0.739	0.481
	17.72	3.950	4.388	7.527	0.965	0.398	0.330		20.93	3.998	4.390	7.532	0.942	0.402	0.413
23.27	4.070	4.352	7.555	1.006	0.199	0.272		27.04	4.151	4.352	7.560	0.975	0.208	0.361	
25.20	4.127	4.323	7.577	1.060	0.099	0.245		29.47	4.229	4.314	7.582	1.020	0.103	0.327	
26.44	4.176	4.297	7.622	1.185	0.019	0.212		30.94	4.313	4.264	7.646	1.193	0.010	0.289	
26.61	4.191	4.304	7.653	1.278	0.006	0.206		31.02	4.323	4.270	7.669	1.261	0.004	0.285	
15.....	0.00	4.260	4.490	7.524	0.780	0.739	0.478	15.....	0.00	4.245	4.488	7.524	0.773	0.739	0.541
	9.38	4.477	4.469	7.558	0.786	0.398	0.390		10.88	4.510	4.472	7.560	0.769	0.398	0.477
12.35	4.599	4.430	7.586	0.833	0.199	0.336		14.22	4.665	4.430	7.590	0.807	0.199	0.424	
13.43	4.655	4.398	7.608	0.886	0.100	0.306		15.37	4.741	4.387	7.613	0.859	0.099	0.395	
14.20	4.717	4.360	7.671	1.073	0.010	0.275		16.17	4.824	4.319	7.677	1.042	0.010	0.362	
14.24	4.725	4.366	7.694	1.142	0.004	0.270		16.22	4.832	4.323	7.700	1.112	0.004	0.358	
30.....	0.00	5.044	4.601	7.570	0.525	0.739	0.618	30.....	0.00	5.035	4.601	7.569	0.522	0.739	0.669
	4.18	5.243	4.575	7.602	0.545	0.393	0.527		4.61	5.264	4.578	7.603	0.537	0.394	0.607
5.59	5.347	4.525	7.629	0.599	0.196	0.464		6.15	5.394	4.519	7.631	0.588	0.197	0.556	
6.13	5.397	4.477	7.650	0.659	0.098	0.433		6.71	5.454	4.457	7.652	0.644	0.099	0.524	
6.53	5.451	4.407	7.721	0.876	0.007	0.394		7.16	5.529	4.322	7.746	0.924	0.004	0.484	
60.....	0.00	5.685	4.680	7.605	0.327	0.739	0.759	60.....	0.00	5.680	4.680	7.605	0.325	0.739	0.793
	2.37	5.837	4.632	7.632	0.357	0.406	0.653		2.54	5.833	4.647	7.634	0.354	0.404	0.720
3.29	5.920	4.579	7.657	0.413	0.211	0.584		3.51	5.951	4.568	7.659	0.408	0.208	0.662	
3.68	5.964	4.500	7.679	0.480	0.103	0.542		3.92	6.009	4.445	7.683	0.479	0.101	0.621	
3.99	6.012	4.340	7.785	0.809	0.002	0.493		4.20	6.060	4.014	7.740	0.659	0.015	0.590	
120.....	0.00	6.213	4.729	7.631	0.161	0.739	0.862	120.....	0.00	6.210	4.729	7.631	0.160	0.739	0.883
	1.74	6.327	4.679	7.656	0.200	0.404	0.736		1.81	6.339	4.679	7.657	0.199	0.405	0.794
2.45	6.388	4.583	7.678	0.262	0.209	0.659		2.59	6.419	4.541	7.682	0.266	0.199	0.724	
2.77	6.425	4.438	7.701	0.339	0.105	0.613		2.90	6.467	4.127	7.706	0.346	0.100	0.689	
2.98	6.452	4.043	7.742	0.476	0.027	0.579		2.97	6.479	3.664	7.716	0.375	0.077	0.619	
3.03	6.456	3.595	7.781	0.596	0.007	0.568									

TABLE 14
CASE O, $d/H_P = 0.70$, $k_{11} = 1$, $X_e = 0.739$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	X_c	q_{core}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
10	0.00	3.715	4.407	0.739	7.492	0.954	0.739	0.481	2.0(-8)
9.35	22.22	3.916	4.378	0.739	7.525	0.964	0.395	0.401	4.7(-8)
8.88	29.05	4.043	4.325	0.739	7.555	1.015	0.198	0.350	9.8(-8)
8.61	31.24	4.099	4.281	0.739	7.575	1.063	0.107	0.326	1.5(-7)
8.23	33.09	4.175	4.206	0.739	7.645	1.267	0.008	0.300	2.9(-7)
8.21	33.15	4.184	4.211	0.739	7.668	1.337	0.004	0.296	2.9(-7)
15	0.00	4.245	4.488	0.739	7.524	0.773	0.739	0.541	5.5(-8)
14.1.....	11.17	4.452	4.463	0.739	7.556	0.790	0.399	0.479	1.4(-7)
13.3.....	14.87	4.589	4.405	0.739	7.588	0.845	0.195	0.430	3.1(-7)
12.9.....	16.06	4.651	4.352	0.739	7.610	0.901	0.100	0.407	5.3(-7)
12.2.....	16.99	4.725	4.263	0.739	7.681	1.110	0.007	0.390	1.0(-6)
30	0.00	5.035	4.601	0.739	7.569	0.522	0.739	0.669	2.5(-7)
28.3	4.69	5.225	4.573	0.739	7.601	0.552	0.395	0.615	6.2(-7)
26.9.....	6.26	5.340	4.508	0.739	7.628	0.610	0.204	0.575	1.3(-6)
24.0.....	7.34	5.467	4.256	0.739	7.715	0.863	0.095	0.561	7.0(-6)
23.8.....	7.36	5.473	4.245	0.739	7.739	0.934	0.004	0.560	7.4(-6)
60	0.00	5.680	4.680	0.739	7.605	0.325	0.739	0.793	8.1(-7)
57.1.....	2.57	5.828	4.644	0.739	7.632	0.364	0.404	0.730	1.8(-6)
54.5.....	3.60	5.931	4.542	0.739	7.660	0.432	0.198	0.692	4.2(-6)
52.1.....	3.98	5.979	4.411	0.739	7.682	0.496	0.102	0.683	1.1(-5)
47.5.....	4.21	6.022	4.202	0.731	7.715	0.598	0.031	0.720	2.7(-5)
45.5.....	4.29	6.041	4.321	0.626	7.767	0.753	0.004	0.734	2.0(-5)
120	0.00	6.210	4.729	0.739	7.631	0.160	0.739	0.883	2.0(-6)
115.1	1.82	6.324	4.678	0.739	7.656	0.207	0.405	0.808	4.2(-6)
109.8.....	2.62	6.409	4.502	0.739	7.683	0.284	0.198	0.770	1.3(-5)
102.8.....	2.93	6.453	4.351	0.656	7.705	0.355	0.100	0.783	3.1(-5)
100.6.....	2.99	6.460	4.338	0.612	7.710	0.371	0.076	0.795	3.2(-5)
94.3.....	3.18	6.499	4.398	0.448	7.788	0.607	0.004	0.808	3.4(-5)

TABLE 15
CASE O, $d/H_P = 0.70$, $k_{11} = 3$, $X_e = 0.739$, $Z_e = 0.021$, MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	X_c	q_{core}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
10	0.00	3.715	4.407	0.739	7.492	0.954	0.739	0.481	5.9(-8)
8.19	23.63	3.775	4.352	0.739	7.517	1.022	0.404	0.404	1.1(-7)
6.82	32.80	3.798	4.277	0.739	7.540	1.096	0.201	0.366	2.0(-7)
5.89	36.22	3.821	4.200	0.739	7.562	1.182	0.100	0.344	3.7(-7)
5.01	38.21	3.825	4.157	0.739	7.595	1.287	0.030	0.352	5.3(-7)
4.65	38.87	3.842	4.184	0.718	7.642	1.433	0.004	0.352	5.4(-7)
15	0.0	4.245	4.488	0.739	7.524	0.773	0.739	0.541	1.7(-7)
12.3.....	11.98	4.333	4.440	0.739	7.551	0.838	0.398	0.476	3.4(-7)
10.2.....	16.30	4.389	4.370	0.739	7.576	0.914	0.200	0.449	6.8(-7)
8.4.....	18.22	4.435	4.309	0.739	7.605	1.008	0.081	0.469	1.3(-6)
7.1.....	19.17	4.473	4.371	0.588	7.671	1.207	0.006	0.492	1.3(-6)
30	0.00	5.035	4.601	0.739	7.569	0.522	0.739	0.669	7.5(-7)
25.0	4.83	5.141	4.561	0.739	7.596	0.585	0.400	0.622	1.6(-6)
20.9.....	6.64	5.227	4.500	0.739	7.624	0.664	0.201	0.632	3.3(-6)
20.0.....	6.88	5.242	4.495	0.728	7.630	0.683	0.168	0.643	3.7(-6)
18.3.....	7.33	5.273	4.515	0.617	7.646	0.730	0.101	0.657	4.1(-6)
16.0.....	7.87	5.335	4.587	0.432	7.727	0.971	0.005	0.688	4.2(-6)
60	0.0	5.680	4.680	0.739	7.605	0.325	0.739	0.793	2.4(-6)
51.4.....	2.63	5.783	4.639	0.739	7.631	0.389	0.403	0.755	4.9(-6)
47.7.....	3.26	5.827	4.612	0.738	7.644	0.426	0.291	0.759	6.9(-6)
44.5.....	3.68	5.863	4.613	0.631	7.656	0.464	0.205	0.768	8.3(-6)
41.4.....	4.02	5.901	4.621	0.519	7.673	0.513	0.124	0.784	9.8(-6)
36.9.....	4.44	5.969	4.685	0.332	7.768	0.798	0.004	0.804	1.1(-5)
120	0.00	6.210	4.729	0.739	7.631	0.160	0.739	0.883	6.1(-6)
102.9.....	2.04	6.312	4.683	0.685	7.659	0.238	0.362	0.843	1.2(-5)
93.5.....	2.68	6.374	4.677	0.509	7.681	0.306	0.194	0.853	1.7(-5)
87.3.....	3.00	6.414	4.682	0.382	7.703	0.375	0.093	0.860	2.1(-5)
81.9.....	3.25	6.459	4.721	0.251	7.785	0.624	0.005	0.864	2.2(-5)

TABLE 16
CASE L, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_p = 0.4$, POST-MAIN SEQUENCE

$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	q_{env}
A. $M/M_\odot = 10$								
21.141	4.068	4.373	7.710	1.642	0.979	0.035	0.142	...
21.151	4.042	4.360	7.693	1.949	0.979	0.000	0.142	...
21.228	4.101	4.249	7.841	2.922	0.979	0.000	0.137	...
21.265	4.076	4.134	7.988	3.350	0.979	0.000	0.142	...
21.289	3.976	3.926	8.097	3.629	0.979	0.000	0.146	...
21.296	3.848	3.749	8.144	3.679	0.978	0.008	0.148	...
21.299	3.674	3.618	8.160	3.665	0.977	0.017	0.148	...
21.332	4.128	3.552	8.168	3.536	0.969	0.047	0.153	0.231
21.621	4.096	3.562	8.180	3.458	0.900	0.055	0.175	0.258
22.011	4.052	3.567	8.192	3.416	0.800	0.062	0.189	0.307
22.347	4.010	3.572	8.200	3.400	0.692	0.065	0.197	0.404
22.776	3.960	3.590	8.215	3.395	0.540	0.071	0.206	0.743
22.835	4.054	3.701	8.218	3.393	0.527	0.072	0.208	...
22.847	4.138	3.808	8.219	3.394	0.521	0.071	0.208	...
22.855	4.161	3.892	8.219	3.395	0.518	0.071	0.208	...
22.866	4.171	3.973	8.219	3.397	0.514	0.071	0.209	...
22.936	4.166	4.056	8.220	3.399	0.487	0.071	0.210	...
23.202	4.196	4.124	8.233	3.402	0.399	0.075	0.218	...
23.502	4.213	4.166	8.246	3.410	0.293	0.079	0.226	...
23.703	4.225	4.178	8.262	3.437	0.215	0.081	0.231	...
23.997	4.231	4.156	8.293	3.496	0.103	0.084	0.235	...
24.239	4.203	4.040	8.400	3.832	0.001	0.049	0.239	...
B. $M/M_\odot = 15$								
11.850	4.619	4.449	7.783	1.574	0.979	0.026	0.185	...
11.857	4.589	4.422	7.787	1.898	0.979	0.000	0.175	...
11.888	4.634	4.260	7.996	2.868	0.979	0.000	0.152	...
11.894	4.625	4.187	8.068	3.072	0.979	0.000	0.175	...
11.904	4.533	3.915	8.202	3.312	0.976	0.027	0.182	...
11.907	4.402	3.696	8.210	3.278	0.974	0.052	0.184	...
11.907	4.319	3.602	8.211	3.272	0.974	0.055	0.184	0.881
11.918	4.716	3.561	8.213	3.221	0.965	0.072	0.190	0.276
12.014	4.697	3.563	8.220	3.162	0.898	0.083	0.212	0.282
12.154	4.667	3.566	8.230	3.134	0.793	0.100	0.233	0.295
12.259	4.624	3.569	8.240	3.123	0.706	0.106	0.240	0.325
12.340	4.592	3.573	8.248	3.124	0.607	0.110	0.245	0.380
12.514	4.554	3.587	8.265	3.141	0.456	0.118	0.253	0.698
12.546	4.643	3.677	8.266	3.137	0.454	0.119	0.254	...
12.549	4.696	3.804	8.266	3.138	0.450	0.119	0.255	...
12.558	4.732	4.037	8.267	3.140	0.442	0.118	0.255	...
12.604	4.715	4.190	8.270	3.147	0.392	0.118	0.257	...
12.704	4.726	4.239	8.283	3.165	0.301	0.124	0.263	...
12.784	4.736	4.264	8.300	3.198	0.217	0.129	0.269	...
12.893	4.741	4.273	8.322	3.248	0.117	0.132	0.274	...
13.030	4.726	4.173	8.447	3.617	0.001	0.109	0.277	...
C. $M/M_\odot = 30$								
5.763	5.379	4.539	7.907	1.538	0.979	0.081	0.309	...
5.767	5.360	4.507	8.018	1.997	0.979	0.009	0.290	...
5.773	5.365	4.396	8.203	2.630	0.979	0.010	0.285	...
5.777	5.351	4.205	8.274	2.802	0.971	0.157	0.294	...
5.779	5.338	4.041	8.274	2.793	0.967	0.173	0.297	...
5.780	5.320	3.875	8.275	2.791	0.964	0.178	0.298	...
5.781	5.209	3.619	8.275	2.790	0.962	0.181	0.299	0.876
5.782	5.433	3.600	8.275	2.791	0.962	0.184	0.300	0.381
5.801	5.411	3.602	8.279	2.776	0.902	0.200	0.316	0.366
5.854	5.364	3.605	8.286	2.776	0.806	0.215	0.327	0.378
5.904	5.328	3.609	8.295	2.787	0.697	0.226	0.335	0.438
5.947	5.317	3.613	8.302	2.799	0.603	0.232	0.339	0.565
5.970	5.316	3.617	8.307	2.809	0.554	0.234	0.340	0.657
5.981	5.408	3.769	8.310	2.814	0.533	0.236	0.342	...
5.982	5.424	3.895	8.310	2.814	0.530	0.236	0.342	...
5.984	5.444	4.060	8.310	2.815	0.526	0.235	0.366	...
5.988	5.453	4.235	8.311	2.816	0.516	0.233	0.344	...
6.039	5.452	4.306	8.321	2.838	0.403	0.236	0.347	...
6.089	5.458	4.314	8.334	2.867	0.304	0.242	0.351	...
6.142	5.461	4.317	8.352	2.907	0.208	0.250	0.356	...
6.179	5.462	4.319	8.366	2.943	0.142	0.253	0.358	...
6.219	5.463	4.312	8.395	3.025	0.075	0.256	0.361	...
6.266	5.435	4.223	8.516	3.386	0.001	0.233	0.363	...

TABLE 17
CASE L, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_P = 1$, POST-MAIN SEQUENCE

$t(10^6 \text{ yr})$	$\log L / L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	q_{env}
A. $M / M_\odot = 10$								
21.438	4.073	4.372	7.714	1.656	0.979	0.035	0.150	...
21.450	4.049	4.355	7.701	1.993	0.979	0.000	0.150	...
21.511	4.107	4.263	7.820	2.816	0.979	0.000	0.148	...
21.558	4.074	4.108	8.011	3.383	0.979	0.000	0.148	...
21.577	3.981	3.914	8.098	3.610	0.979	0.000	0.149	...
21.582	3.895	3.786	8.133	3.652	0.978	0.004	0.150	...
21.585	3.751	3.626	8.153	3.657	0.977	0.012	0.150	...
21.587	3.655	3.572	8.159	3.651	0.977	0.017	0.150	0.883
21.588	3.869	3.532	8.163	3.642	0.976	0.023	0.150	0.353
21.617	4.132	3.505	8.168	3.530	0.969	0.047	0.155	0.228
21.858	4.108	3.508	8.179	3.459	0.901	0.050	0.173	0.246
22.170	4.052	3.515	8.190	3.418	0.803	0.058	0.187	0.280
22.475	3.991	3.523	8.201	3.399	0.702	0.066	0.196	0.375
22.712	3.957	3.530	8.208	3.397	0.602	0.067	0.201	0.526
22.950	3.933	3.537	8.219	3.403	0.496	0.068	0.205	0.737
23.014	4.124	3.726	8.221	3.399	0.494	0.071	0.207	...
23.026	4.184	3.925	8.221	3.401	0.489	0.068	0.207	...
23.222	4.183	4.107	8.229	3.409	0.400	0.072	0.211	...
23.444	4.201	4.148	8.244	3.424	0.293	0.074	0.218	...
23.626	4.216	4.173	8.262	3.456	0.202	0.076	0.224	...
23.754	4.223	4.181	8.269	3.458	0.178	0.080	0.228	...
23.914	4.224	4.168	8.289	3.505	0.099	0.080	0.229	...
24.149	4.198	4.059	8.398	3.831	0.001	0.055	0.233	...
B. $M / M_\odot = 15$								
12.031	4.633	4.444	7.778	1.510	0.979	0.080	0.201	...
12.038	4.610	4.424	7.821	1.924	0.979	0.000	0.201	...
12.059	4.652	4.277	8.021	2.819	0.979	0.000	0.193	...
12.068	4.627	4.133	8.148	3.190	0.979	0.000	0.195	...
12.073	4.583	3.983	8.208	3.260	0.976	0.035	0.197	...
12.075	4.529	3.818	8.215	3.233	0.974	0.059	0.199	...
12.076	4.482	3.711	8.215	3.224	0.972	0.062	0.199	...
12.077	4.319	3.534	8.216	3.216	0.972	0.069	0.200	0.887
12.086	4.725	3.485	8.215	3.182	0.964	0.078	0.203	0.290
12.167	4.710	3.486	8.223	3.143	0.902	0.090	0.221	0.298
12.285	4.685	3.489	8.232	3.121	0.801	0.100	0.236	0.310
12.401	4.656	3.491	8.241	3.113	0.697	0.107	0.246	0.327
12.500	4.627	3.495	8.251	3.114	0.606	0.115	0.254	0.354
12.618	4.602	3.498	8.262	3.122	0.500	0.122	0.260	0.401
12.708	4.588	3.500	8.271	3.136	0.402	0.124	0.262	0.447
12.814	4.580	3.503	8.284	3.157	0.306	0.128	0.266	0.507
12.866	4.579	3.504	8.293	3.176	0.249	0.130	0.267	0.536
12.994	4.584	3.503	8.322	3.248	0.118	0.132	0.270	0.509
13.125	4.650	3.493	8.410	3.502	0.007	0.127	0.274	0.352
C. $M / M_\odot = 30$								
5.774	5.384	4.535	7.902	1.515	0.979	0.093	0.304	...
5.779	5.366	4.498	8.030	2.033	0.979	0.009	0.297	...
5.784	5.372	4.391	8.200	2.614	0.979	0.007	0.291	...
5.788	5.363	4.250	8.273	2.804	0.974	0.133	0.295	...
5.789	5.352	4.112	8.275	2.796	0.969	0.161	0.298	...
5.791	5.335	3.967	8.275	2.791	0.966	0.172	0.300	...
5.791	5.313	3.806	8.275	2.790	0.965	0.177	0.301	...
5.792	5.280	3.684	8.275	2.789	0.964	0.180	0.301	...
5.792	5.156	3.515	8.276	2.791	0.963	0.180	0.301	...
5.795	5.468	3.481	8.274	2.783	0.956	0.183	0.302	0.382
5.820	5.455	3.479	8.280	2.774	0.901	0.200	0.318	0.382
5.860	5.429	3.478	8.286	2.771	0.809	0.215	0.332	0.384
5.907	5.400	3.480	8.296	2.781	0.701	0.229	0.343	0.393
5.950	5.379	3.481	8.304	2.792	0.603	0.238	0.349	0.404
5.995	5.367	3.483	8.312	2.807	0.505	0.246	0.353	0.414
6.059	5.360	3.484	8.328	2.844	0.366	0.252	0.357	0.422
6.084	5.361	3.484	8.335	2.860	0.306	0.255	0.357	0.422
6.136	5.368	3.483	8.354	2.910	0.194	0.257	0.359	0.415
6.185	5.384	3.481	8.380	2.979	0.109	0.260	0.361	0.404
6.234	5.415	3.479	8.437	3.146	0.023	0.257	0.361	0.390

TABLE 17—Continued

$t(10^6 \text{ yr})$	$\log L / L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	q_{env}
D. $M / M_\odot = 60$								
3.712	5.941	4.578	8.054	1.711	0.979	0.184	0.384	...
3.713	5.931	4.562	8.109	1.910	0.979	0.166	0.392	...
3.717	5.989	4.358	8.275	2.454	0.977	0.187	0.374	...
3.737	6.011	4.220	8.312	2.561	0.906	0.282	0.374	...
3.768	6.012	4.194	8.319	2.575	0.792	0.285	0.378	...
3.794	6.013	4.190	8.326	2.589	0.697	0.288	0.379	...
3.825	6.014	4.182	8.334	2.609	0.594	0.294	0.381	...
3.853	6.015	4.175	8.342	2.627	0.496	0.298	0.384	...
3.884	6.015	4.166	8.351	2.649	0.398	0.302	0.386	...
3.912	6.016	4.153	8.365	2.684	0.304	0.306	0.388	...
3.949	6.016	4.134	8.379	2.722	0.201	0.310	0.390	...
3.982	6.016	4.105	8.407	2.802	0.108	0.314	0.392	...
4.026	6.010	3.977	8.512	3.117	0.006	0.307	0.388	...
E. $M / M_\odot = 120$								
2.868	6.406	4.598	8.061	1.465	0.979	0.348	0.477	...
2.874	6.383	4.408	8.239	2.097	0.979	0.295	0.409	...
2.876	6.441	4.280	8.280	2.258	0.978	0.287	0.369	...
2.876	6.443	4.214	8.292	2.295	0.978	0.283	0.369	...
2.903	6.449	4.090	8.328	2.414	0.895	0.291	0.360	...
2.934	6.449	4.079	8.334	2.427	0.800	0.294	0.364	...
2.965	6.450	4.072	8.340	2.442	0.705	0.298	0.365	...
2.996	6.451	4.061	8.347	2.460	0.610	0.302	0.369	...
3.035	6.451	4.047	8.358	2.487	0.494	0.307	0.373	...
3.068	6.449	4.057	8.366	2.519	0.400	0.299	0.362	...
3.101	6.450	4.043	8.379	2.553	0.305	0.302	0.364	...
3.151	6.451	4.015	8.404	2.624	0.173	0.309	0.369	...
3.181	6.450	3.973	8.428	2.696	0.098	0.307	0.364	...
3.221	6.442	3.863	8.526	3.006	0.011	0.291	0.347	...
3.227	6.431	3.746	8.634	3.332	0.001	0.270	0.346	...

TABLE 18A

CASE L, $M_i / M_\odot = 15$, $k_{11} = 1$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_P = 1$, POST-MAIN SEQUENCE

M / M_\odot	$t(10^6 \text{ yr})$	$\log L / L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	q_{env}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
15.000.....	12.031	4.633	4.444	0.739	7.778	1.510	0.979	0.000	0.201	...	...
	12.038	4.610	4.424	0.739	7.821	1.924	0.979	0.000	0.201	...	...
	12.059	4.652	4.277	0.739	8.021	2.819	0.979	0.000	0.193	...	...
	12.068	4.627	4.133	0.739	8.148	3.190	0.979	0.000	0.195	...	...
	12.073	4.583	3.983	0.739	8.208	3.260	0.976	0.035	0.197	...	...
14.999.....	12.075	4.540	3.820	0.739	8.215	3.233	0.974	0.059	0.199	...	3.0(-6)
14.995.....	12.077	4.474	3.673	0.739	8.216	3.223	0.973	0.066	0.199	...	5.0(-6)
14.990.....	12.077	4.333	3.532	0.739	8.216	3.216	0.972	0.069	0.200	0.822	6.0(-6)
14.743.....	12.086	4.725	3.483	0.707	8.215	3.183	0.964	0.079	0.206	0.295	3.0(-5)
11.935.....	12.171	4.709	3.475	0.707	8.223	3.142	0.899	0.113	0.279	0.375	3.6(-5)
9.261.....	12.237	4.694	3.469	0.707	8.229	3.127	0.845	0.158	0.375	0.488	4.5(-5)
6.738.....	12.285	4.682	3.465	0.707	8.233	3.121	0.800	0.224	0.527	0.672	6.0(-5)
5.133.....	12.310	4.676	3.475	0.707	8.235	3.118	0.777	0.296	0.642	...	7.2(-5)
4.407.....	12.334	4.669	3.911	0.707	8.236	3.118	0.762	0.354	0.825	...	...
	12.357	4.661	4.004	0.707	8.238	3.115	0.740	0.359	0.830	...	...
	12.428	4.639	4.182	0.707	8.244	3.114	0.668	0.370	0.845	...	...
	12.494	4.616	4.304	0.707	8.249	3.114	0.611	0.388	0.847	...	...
	12.596	4.579	4.427	0.707	8.260	3.124	0.520	0.407	0.874	...	...
	12.711	4.545	4.505	0.707	8.272	3.139	0.396	0.420	0.895	...	...
	12.781	4.532	4.532	0.707	8.281	3.158	0.340	0.430	0.896	...	...
	12.907	4.522	4.557	0.707	8.300	3.198	0.205	0.441	0.904	...	...
	13.001	4.538	4.553	0.707	8.323	3.256	0.112	0.443	0.912	...	...
	13.129	4.649	4.432	0.707	8.410	3.510	0.006	0.417	0.913	...	...
	13.137	4.698	4.302	0.707	8.444	3.616	0.001	0.362	0.913	...	...

NOTE.—Mass loss only for $\log T_e < 3.85$.

TABLE 18B
CASE L, $M_i/M_\odot = 30$, $k_{11} = 1$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_P = 1$, POST-MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	q_{env}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
30.000.....	5.774	5.384	4.535	0.739	7.902	1.515	0.979	0.093	0.304	...	...
	5.779	5.366	4.498	0.739	8.030	2.033	0.979	0.009	0.297	...	...
	5.784	5.372	4.391	0.739	8.200	2.614	0.979	0.007	0.291	...	...
	5.788	5.359	4.211	0.739	8.274	2.801	0.972	0.147	0.296	...	...
	5.790	5.345	4.051	0.739	8.275	2.793	0.968	0.170	0.299	...	...
	5.791	5.332	3.928	0.739	8.275	2.791	0.966	0.173	0.300	...	...
29.992.....	5.792	5.288	3.741	0.739	8.275	2.789	0.964	0.181	0.301	...	2.7(-5)
29.974.....	5.792	5.158	3.507	0.739	8.278	2.795	0.963	0.181	0.302	...	5.9(-5)
29.595.....	5.794	5.468	3.480	0.675	8.275	2.783	0.958	0.186	0.307	0.386	2.0(-4)
24.836.....	5.817	5.453	3.476	0.675	8.279	2.774	0.906	0.237	0.382	0.460	2.2(-4)
19.096.....	5.840	5.436	3.476	0.675	8.284	2.774	0.856	0.331	0.513	0.600	2.8(-4)
12.026.....	5.866	5.408	3.507	0.675	8.287	2.773	0.803	0.540	0.829	...	3.6(-4)
11.388.....	5.868	5.397	3.646	0.675	8.289	2.774	0.800	0.581	0.881	...	2.7(-4)
11.335.....	5.868	5.397	3.990	0.590	8.289	2.775	0.800	0.581	0.885	...	...
	5.878	5.393	4.280	0.590	8.288	2.772	0.778	0.582	0.885	...	...
	5.905	5.371	4.460	0.590	8.293	2.778	0.718	0.603	0.900	...	...
	5.956	5.339	4.618	0.590	8.303	2.793	0.600	0.628	0.915	...	...
	6.023	5.326	4.666	0.590	8.317	2.823	0.452	0.650	0.924	...	...
	6.044	5.327	4.666	0.590	8.322	2.834	0.403	0.654	0.925	...	...
	6.094	5.333	4.657	0.590	8.337	2.870	0.290	0.660	0.928	...	...
	6.138	5.343	4.636	0.590	8.353	2.913	0.208	0.667	0.930	...	...
	6.191	5.361	4.587	0.590	8.378	2.982	0.102	0.672	0.932	...	...
	6.229	5.381	4.517	0.590	8.413	3.088	0.037	0.671	0.934	...	...

NOTE.—Mass loss only for $\log T_e < 3.85$.

TABLE 19
CASE L, $M_i/M_\odot = 30$, $k_{11} = 100$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_P = 1$, POST-MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}
30.000.....	5.774	5.384	4.535	0.739	7.902	1.515	0.979	0.093	0.304
	5.779	5.366	4.498	0.739	8.030	2.033	0.979	0.009	0.297
	5.784	5.372	4.391	0.739	8.200	2.614	0.979	0.007	0.291
	5.788	5.363	4.250	0.739	8.273	2.804	0.974	0.133	0.295
	5.789	5.352	4.112	0.739	8.275	2.796	0.969	0.161	0.298
	5.791	5.335	3.967	0.739	8.275	2.791	0.966	0.172	0.300
	5.791	5.313	3.806	0.739	8.275	2.790	0.965	0.177	0.301
	5.792	5.304	3.713	0.739	8.275	2.789	0.965	0.180	0.301
	5.793	5.470	3.739	0.394	8.276	2.788	0.961	0.470	0.778
	5.805	5.464	3.939	0.394	8.277	2.777	0.932	0.498	0.805
11.625.....	5.820	5.456	4.205	0.394	8.280	2.773	0.899	0.520	0.826
	5.866	5.432	4.528	0.394	8.288	2.772	0.795	0.565	0.865
	5.907	5.413	4.650	0.394	8.294	2.777	0.703	0.592	0.887
	5.956	5.391	4.739	0.394	8.304	2.792	0.594	0.619	0.904
	5.993	5.380	4.775	0.394	8.311	2.803	0.508	0.634	0.914
	6.041	5.369	4.805	0.394	8.324	2.831	0.403	0.650	0.918
	6.089	5.368	4.816	0.394	8.337	2.863	0.293	0.661	0.918
	6.131	5.378	4.810	0.394	8.353	2.906	0.199	0.666	0.930
	6.185	5.394	4.797	0.394	8.379	2.976	0.102	0.676	0.935
	6.239	5.439	4.732	0.394	8.452	3.187	0.012	0.664	0.940
	6.247	5.475	4.610	0.394	8.512	3.370	0.001	0.612	0.940

NOTE.—Mass loss only for $\log T_e < 3.70$.

TABLE 20
CASE S, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_p = 0.4$, POST-MAIN SEQUENCE

$t(10^6 \text{ yr})$	$\log L / L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	q_{env}
A. $M / M_\odot = 10$								
21.260	4.069	4.373	7.712	1.681	0.979	0.020	0.146	...
21.262	4.061	4.371	7.696	1.721	0.979	0.000	0.161	...
21.358	4.106	4.267	7.874	3.029	0.979	0.000	0.136	...
21.421	4.070	4.090	8.148	3.665	0.977	0.012	0.147	...
21.436	4.061	4.015	8.166	3.591	0.974	0.040	0.148	...
21.476	4.082	3.949	8.167	3.537	0.965	0.046	0.152	...
21.691	4.111	4.000	8.172	3.511	0.914	0.048	0.159	...
22.151	4.128	3.966	8.185	3.472	0.795	0.054	0.173	...
22.491	4.135	3.922	8.196	3.450	0.703	0.060	0.182	...
22.767	4.142	3.879	8.204	3.439	0.603	0.061	0.189	...
23.134	4.135	3.781	8.216	3.426	0.495	0.065	0.198	...
23.208	4.088	3.672	8.221	3.428	0.463	0.067	0.201	...
23.221	4.033	3.595	8.222	3.428	0.458	0.067	0.201	0.839
23.340	4.076	3.577	8.228	3.432	0.406	0.069	0.203	0.654
23.563	4.089	3.576	8.241	3.449	0.306	0.070	0.208	0.627
23.877	4.109	3.573	8.260	3.472	0.202	0.074	0.213	0.585
24.068	4.129	3.569	8.283	3.523	0.114	0.075	0.217	0.528
24.354	4.230	3.556	8.391	3.844	0.001	0.050	0.223	0.340
B. $M / M_\odot = 15$								
11.993	4.619	4.449	7.781	1.580	0.979	0.015	0.216	...
11.993	4.616	4.448	7.778	1.600	0.979	0.000	0.209	...
12.025	4.650	4.313	8.079	3.014	0.979	0.000	0.202	...
12.038	4.735	4.196	8.209	3.257	0.975	0.050	0.190	...
12.208	4.741	4.161	8.216	3.195	0.901	0.077	0.200	...
12.356	4.755	4.136	8.225	3.176	0.803	0.082	0.212	...
12.497	4.767	4.109	8.235	3.163	0.701	0.091	0.223	...
12.616	4.777	4.082	8.243	3.161	0.596	0.095	0.230	...
12.736	4.788	4.047	8.255	3.161	0.500	0.104	0.241	...
12.864	4.799	4.007	8.268	3.166	0.391	0.111	0.249	...
12.977	4.806	3.956	8.282	3.180	0.298	0.117	0.258	...
13.157	4.812	3.803	8.312	3.224	0.166	0.130	0.271	...
13.208	4.781	3.601	8.329	3.268	0.115	0.132	0.274	0.879
13.367	4.824	3.568	8.453	3.618	0.001	0.115	0.283	0.506
C. $M / M_\odot = 30$								
6.101	5.408	4.530	7.868	1.365	0.979	0.183	0.309	...
6.101	5.404	4.529	7.857	1.358	0.979	0.141	0.309	...
6.112	5.451	4.351	8.227	2.685	0.978	0.034	0.299	...
6.125	5.477	4.240	8.273	2.789	0.954	0.181	0.299	...
6.155	5.479	4.233	8.276	2.792	0.894	0.184	0.301	...
6.201	5.483	4.227	8.283	2.800	0.800	0.190	0.307	...
6.249	5.486	4.221	8.291	2.810	0.700	0.196	0.311	...
6.298	5.489	4.215	8.298	2.821	0.594	0.202	0.315	...
6.338	5.492	4.202	8.307	2.837	0.512	0.206	0.320	...
6.395	5.495	4.193	8.320	2.861	0.400	0.214	0.324	...
6.447	5.498	4.180	8.332	2.886	0.299	0.219	0.328	...
6.501	5.501	4.161	8.352	2.934	0.205	0.225	0.332	...
6.557	5.503	4.134	8.379	3.004	0.104	0.231	0.336	...
6.614	5.501	4.062	8.441	3.184	0.016	0.233	0.339	...
6.626	5.495	3.990	8.510	3.393	0.001	0.215	0.340	...
D. $M / M_\odot = 60$								
3.830	5.974	4.574	7.940	1.296	0.979	0.290	0.414	...
3.834	6.001	4.469	8.080	1.838	0.979	0.158	0.362	...
3.839	6.020	4.213	8.290	2.511	0.978	0.180	0.361	...
3.842	6.034	4.030	8.308	2.563	0.969	0.255	0.361	...
3.851	6.042	3.940	8.309	2.563	0.935	0.268	0.362	...
3.862	6.043	3.924	8.312	2.568	0.895	0.270	0.363	...
3.886	6.044	3.902	8.318	2.578	0.805	0.276	0.367	...
3.919	6.046	3.868	8.325	2.592	0.692	0.283	0.372	...
3.944	6.048	3.842	8.332	2.607	0.603	0.288	0.376	...
3.972	6.049	3.810	8.341	2.627	0.503	0.294	0.380	...
4.006	6.051	3.762	8.353	2.652	0.398	0.301	0.387	...
4.036	6.053	3.725	8.365	2.685	0.299	0.307	0.390	...
4.074	6.054	3.668	8.383	2.731	0.199	0.313	0.393	...
4.114	6.055	3.644	8.411	2.807	0.102	0.319	0.398	...
4.157	6.047	3.629	8.567	3.270	0.001	0.305	0.403	0.841

TABLE 21
CASE S, $k_{11} = 0$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_P = 1$, POST-MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	q_{env}
120.....	3.103	6.458	4.375	8.078	1.495	0.979	0.415	0.522	...
	3.108	6.456	4.093	8.330	2.318	0.978	0.374	0.513	...
	3.109	6.458	3.850	8.341	2.351	0.973	0.407	0.513	...
	3.110	6.450	3.624	8.343	2.357	0.969	0.420	0.513	...
	3.125	6.507	3.576	8.341	2.349	0.905	0.429	0.513	0.750
	3.153	6.509	3.576	8.348	2.366	0.792	0.436	0.518	0.745
	3.177	6.510	3.576	8.354	2.381	0.697	0.442	0.524	0.743
	3.203	6.511	3.576	8.362	2.400	0.600	0.450	0.529	0.740
	3.228	6.512	3.571	8.371	2.423	0.498	0.457	0.532	0.738
	3.255	6.513	3.570	8.378	2.447	0.402	0.463	0.537	0.737
	3.287	6.515	3.570	8.396	2.492	0.295	0.468	0.542	0.735
	3.318	6.516	3.570	8.414	2.544	0.193	0.475	0.544	0.733
	3.352	6.517	3.569	8.446	2.636	0.095	0.480	0.547	0.729
	3.381	6.515	3.568	8.552	2.956	0.016	0.475	0.549	0.719

TABLE 22A
CASE S, $M_i/M_\odot = 15$, $k_{11} = 1$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_P = 1$, POST-MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	q_{env}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
13.737.....	12.297	4.546	4.425	0.739	7.779	1.593	0.979	0.023	0.192	...	2.3(-7)
13.736.....	12.302	4.535	4.414	0.739	7.803	1.903	0.979	0.000	0.192	...	2.3(-7)
13.725.....	12.331	4.612	4.254	0.739	8.038	2.973	0.979	0.000	0.192	...	5.8(-7)
13.713.....	12.346	4.605	4.129	0.739	8.201	3.320	0.976	0.038	0.192	...	1.1(-6)
13.671.....	12.371	4.621	3.980	0.739	8.204	3.249	0.961	0.068	0.193	...	2.2(-6)
13.379.....	12.459	4.616	3.832	0.739	8.209	3.234	0.907	0.078	0.204	...	4.4(-6)
13.202.....	12.492	4.606	3.740	0.739	8.211	3.229	0.885	0.079	0.212	...	6.4(-6)
12.976.....	12.515	4.536	3.513	0.739	8.213	3.224	0.875	0.080	0.215	0.846	1.6(-5)

TABLE 22B
CASE S, $M_i/M_\odot = 30$, $k_{11} = 1$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_P = 1$, POST-MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
27.058.....	5.946	5.339	4.507	0.739	7.886	1.529	0.979	0.068	0.304	1.2(-6)
27.045.....	5.955	5.371	4.365	0.739	8.165	2.535	0.979	0.000	0.310	2.4(-6)
26.998.....	5.965	5.406	4.190	0.739	8.269	2.812	0.963	0.176	0.309	6.3(-6)
26.780.....	5.996	5.408	4.174	0.739	8.272	2.812	0.900	0.186	0.312	7.1(-6)
26.443.....	6.040	5.409	4.157	0.739	8.278	2.818	0.806	0.193	0.322	7.9(-6)
26.006.....	6.093	5.410	4.136	0.739	8.287	2.829	0.701	0.205	0.333	8.8(-6)
25.569.....	6.140	5.410	4.115	0.739	8.295	2.839	0.600	0.214	0.345	9.9(-6)
24.953.....	6.197	5.410	4.086	0.739	8.304	2.853	0.491	0.228	0.359	1.1(-5)
24.399.....	6.240	5.409	4.053	0.739	8.315	2.876	0.396	0.239	0.372	1.4(-5)
23.494.....	6.299	5.408	4.004	0.739	8.330	2.906	0.291	0.259	0.393	1.7(-5)
22.580.....	6.344	5.407	3.955	0.739	8.346	2.945	0.199	0.274	0.413	2.2(-5)
20.639.....	6.409	5.403	3.861	0.739	8.377	3.023	0.100	0.310	0.458	3.8(-5)
18.071.....	6.466	5.395	3.803	0.658	8.455	3.249	0.010	0.354	0.528	5.5(-5)
17.690.....	6.472	5.389	3.739	0.632	8.490	3.354	0.003	0.346	0.540	7.3(-5)

TABLE 22C
CASE S, $M_i/M_\odot = 60$, $k_{11} = 1$, $X_e = 0.739$, $Z_e = 0.021$, $\alpha_P = 1$, POST-MAIN SEQUENCE

M/M_\odot	$t(10^6 \text{ yr})$	$\log L/L_\odot$	$\log T_e$	X_{surf}	$\log T_c$	$\log \rho_c$	Y_c	q_{core}	q_{shell}	$-\dot{M}(M_\odot \text{ yr}^{-1})$
54.177.....	3.727	5.917	4.546	0.739	7.944	1.340	0.979	0.284	0.425	3.9(-6)
54.149.....	3.733	5.945	4.388	0.739	8.189	2.196	0.979	0.156	0.398	7.8(-6)
54.132.....	3.734	5.953	4.285	0.739	8.270	2.454	0.979	0.166	0.398	1.4(-5)
53.831.....	3.741	5.983	3.972	0.739	8.309	2.565	0.955	0.298	0.401	6.2(-5)
53.275.....	3.749	5.984	3.950	0.739	8.310	2.566	0.926	0.305	0.409	7.1(-5)
49.870.....	3.786	5.982	3.860	0.739	8.318	2.583	0.793	0.329	0.440	1.1(-4)
47.877.....	3.801	5.981	3.839	0.739	8.322	2.591	0.736	0.345	0.458	1.3(-4)
46.438.....	3.812	5.981	3.859	0.726	8.324	2.596	0.705	0.361	0.469	1.4(-4)
43.754.....	3.840	5.979	4.036	0.652	8.331	2.611	0.606	0.389	0.506	6.4(-5)
42.265.....	3.869	5.977	4.132	0.603	8.340	2.631	0.509	0.410	0.525	4.4(-5)
41.273.....	3.897	5.976	4.192	0.564	8.350	2.654	0.415	0.425	0.545	3.2(-5)
40.152.....	3.936	5.974	4.244	0.520	8.365	2.694	0.294	0.446	0.565	2.6(-5)
39.264.....	3.974	5.973	4.270	0.484	8.380	2.732	0.191	0.462	0.587	2.3(-5)
38.679.....	4.001	5.971	4.282	0.460	8.404	2.799	0.117	0.475	0.596	2.2(-5)
37.668.....	4.045	5.966	4.215	0.417	8.492	3.059	0.012	0.488	0.610	2.8(-5)
37.510.....	4.050	5.963	4.148	0.399	8.540	3.205	0.002	0.473	0.611	3.5(-5)

lished elsewhere (Stothers and Chin 1973b). Tracks for models including uniform rotation and tangled magnetic fields have been tabulated elsewhere, but only for the zero-age and terminal-age main-sequence models (Stothers 1980).

III. INTERCOMPARISON OF MODEL SEQUENCES

In general, the use of any tables of evolutionary sequences of stellar models requires a proper recognition of the limitations of the models. This is especially true in the case of massive stars, for which the variety of possible evolutionary tracks, consistent with presently known observational uncertainties, is bewilderingly large. To orient as well as to caution the potential user, we provide a brief synopsis of the present tracks, without expressing any preference for a particular set of tracks. It is convenient, however, to summarize our results here primarily in terms of the interior mixing scheme used and only secondarily in terms of stellar-wind mass loss and initial chemical composition. For illustration, we select tracks based on $X_e = 0.739$ and $Z_e = 0.021$, since this chemical composition has been our most commonly adopted one.

a) Main Sequence

Intercomparison of the main-sequence evolutionary sequences in ways that have not been *explicitly* done before is interesting and instructive. Figure 1 presents the H-R diagram for a star of $30 M_\odot$ without mass loss, in the case of the three different mixing schemes. Mixing that brings more envelope hydrogen into the convective core, where the fresh

hydrogen is burned into helium, raises the average mean molecular weight of the star and therefore the star's luminosity. Despite the star's higher power output, the lifetime is lengthened owing to the proportionately greater consumption of hydrogen fuel. This is true at all stellar masses, even though for masses below $\sim 10 M_\odot$ semiconvection does not develop at all while for masses above $\sim 60 M_\odot$ in the mixing scheme S, fresh hydrogen becomes suddenly mixed into the core near the end of the main-sequence phase. The behavior of the lifetime for the three different mixing schemes is illustrated in Figure 2. In the limit of extremely high stellar masses, the lifetime approaches an asymptotic minimum equal to 1.46×10^6 yr, irrespective of the mixing scheme adopted (Stothers 1966).

In the models computed with overshooting from the convective core, semiconvective mixing outside the core was completely neglected. Figure 3 indicates those regions of the well-evolved models that are formally unstable according to Schwarzschild's criterion. For $d/H_P = 0.35$, the layers above and below the zero-age core boundary, where the composition gradient begins, are slightly unstable in stars with masses greater than $\sim 15 M_\odot$. This situation implies the local existence of a small semiconvective zone. For $d/H_P = 0.70$, the unstable layers are confined to a narrower region that is located strictly above the zero-age core boundary. Since the composition is homogeneous there, no semiconvective zone is expected to develop unless overshooting convective elements penetrate a significant distance down into the stable inhomogeneous layers below. A recent review of observational and theoretical work done on convective core overshooting in main-sequence stars suggests that $0 < d/H_P < 1.5$ (Stothers and Chin 1990).

If mass loss takes place at a rate given by equation (1) with $k_{11} = 1$ or greater, convective instability outside the core is strongly suppressed at all stellar masses, with or without overshooting from the convective core boundary. Although a value of $k_{11} = 1$ seems to be observationally reasonable for masses higher than $\sim 30 M_\odot$, it is probably too large for significantly lower masses (Stothers and Chin 1979, 1980). In this case, the problem of semiconvection remains for some intermediate mass range, perhaps $10-30 M_\odot$ or $15-30 M_\odot$ (see also Chiosi, Nasi, and Bertelli 1979). At the highest masses of all, stars possibly lose so much mass that they evolve quasi-homogeneously (Simon and Stothers 1970; Stothers and Chin 1979; Maeder 1980); such an extreme case, however, has not been included in the present tables.

b) Post-Main Sequence

Factors that do not greatly change the appearance of the evolutionary track on the H-R diagram during the phase of core hydrogen burning can have a large effect on the subsequent portions of the track. Stellar-wind mass loss is one such factor, and its effect has been thoroughly demonstrated and discussed before for the present evolutionary tracks (Stothers and Chin 1979). A second factor is overshooting from the convective core, which has not been studied by us for post-main-sequence stages of evolution, but has been studied by Maeder and Meynet (1987, 1988, 1989) for a wide range of stellar masses. Third, there is the choice of semicon-

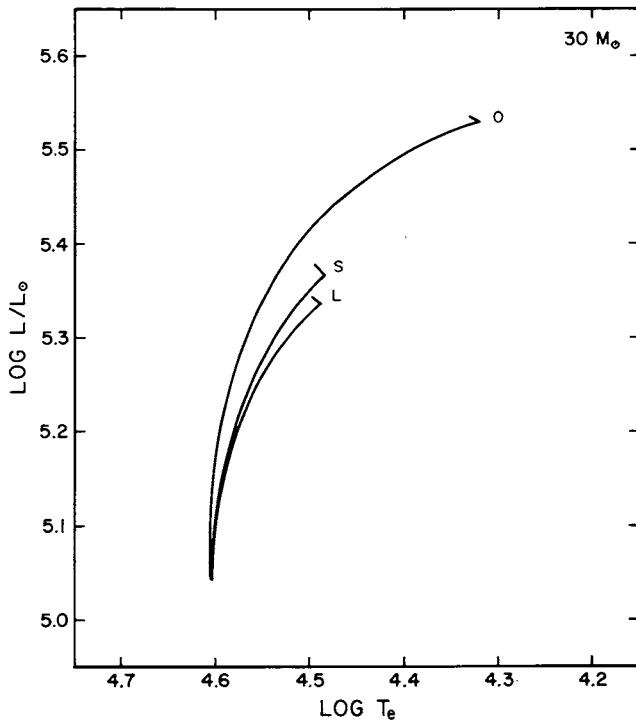


FIG. 1.—H-R diagram showing evolutionary tracks for stellar models of $30 M_\odot$ with three different mixing schemes. Input parameters are $X_e = 0.739$, $Z_e = 0.021$, $k_{11} = 0$, and, for scheme O, $d/H_P = 0.70$. The tracks terminate near the end of central hydrogen burning.

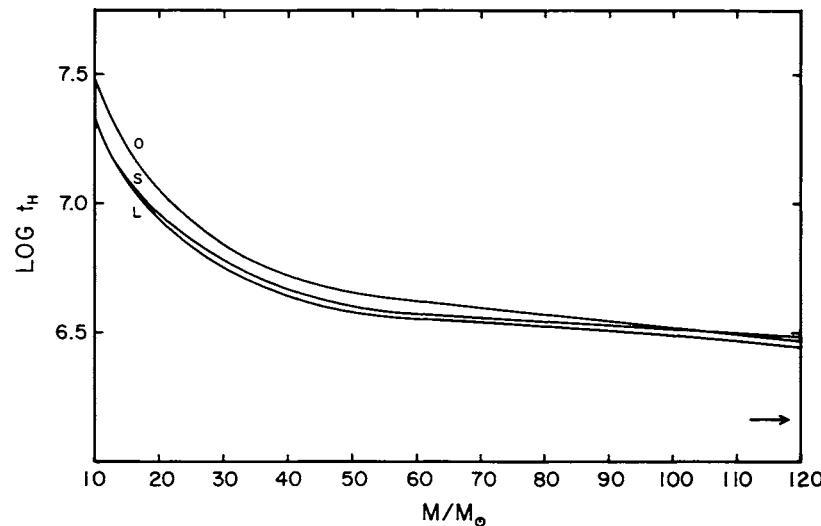


FIG. 2.—Logarithm of the lifetime (in years) of core hydrogen burning as a function of stellar mass, for three different mixing schemes. Input parameters for the models are as in Fig. 1. The arrow indicates the asymptotic limit of the lifetime for extremely high stellar masses.

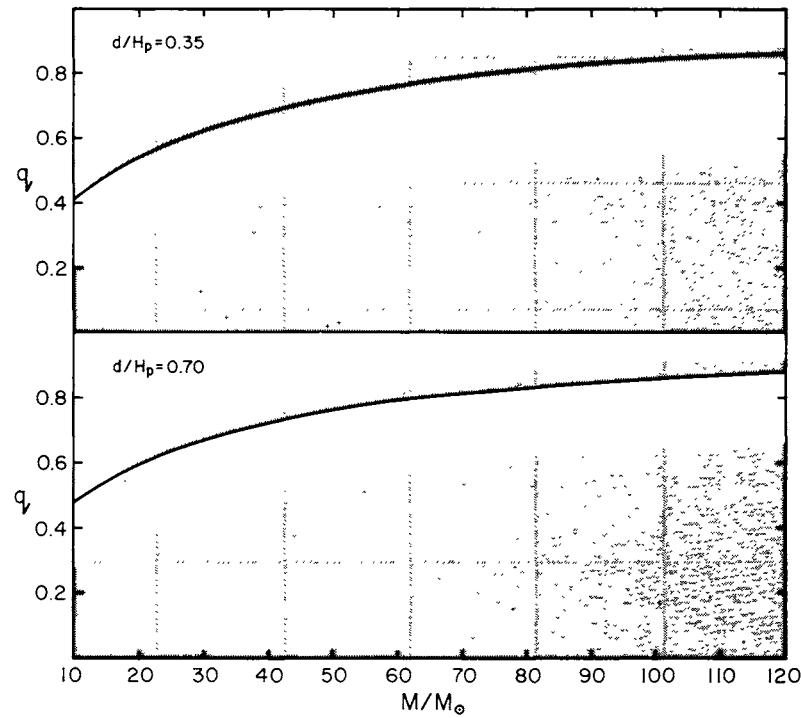


FIG. 3.—Mass fractions of the star for convectively unstable regions at an evolutionary stage near the end of central hydrogen burning are plotted as a function of total stellar mass for mixing scheme O. Input parameters for the models are as in Fig. 1. The solid line shows the location of the zero-age convective core boundary.

vective mixing scheme, which strongly influences the size of the fully convective intermediate zone (FCZ) that develops just outside the helium core after central hydrogen vanishes. Except for stellar masses above $\sim 30 M_{\odot}$, scheme S produces a much larger FCZ than does scheme L.

If the FCZ is sufficiently large, a massive star begins its slow phase of core helium burning as a blue supergiant; if

the FCZ is small, the star initially moves into the red-supergiant configuration (Stothers and Chin 1968; Chiosi and Summa 1970). However, the star's configuration during early helium burning also depends on its initial chemical composition and is bluer for a larger initial helium abundance or a smaller initial metals abundance (Stothers and Chin 1975, 1976). If $Z_e \sim 10^{-3}$, the star is extremely blue (Trimble,

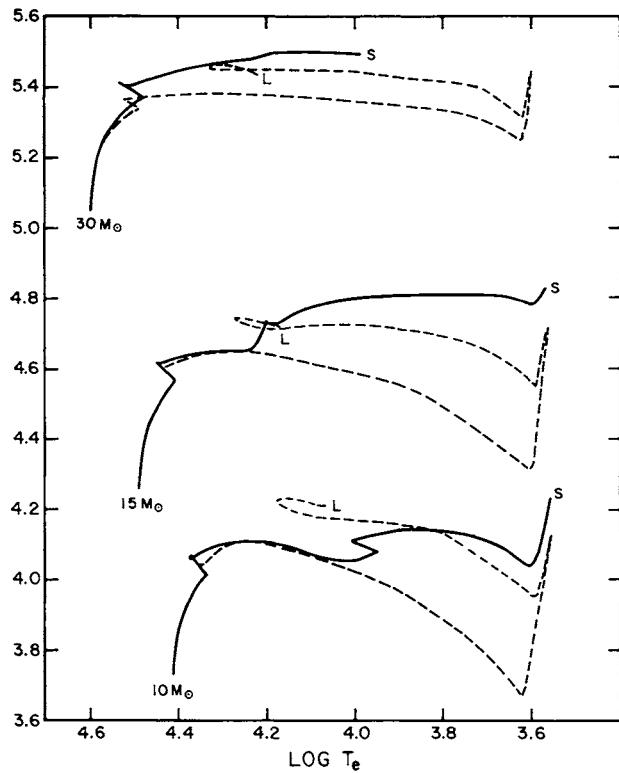


FIG. 4.—H-R diagram showing evolutionary tracks for stellar models of 10, 15, and $30 M_{\odot}$ in the case of mixing schemes L (dashed lines) and S (solid lines). Input parameters are as in Fig. 1; the outer convective envelopes have $\alpha_p = 0.4$. The tracks terminate near the end of central helium burning.

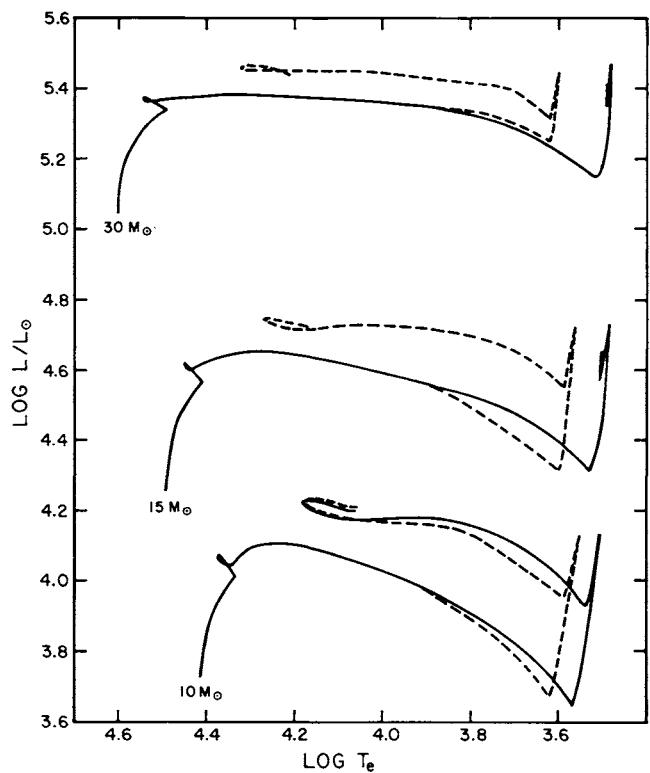


FIG. 5.—H-R diagram showing evolutionary tracks for stellar models of 10, 15, and $30 M_{\odot}$ in the case of mixing scheme L. Input parameters are as in Fig. 1. For the outer convective envelopes, $\alpha_p = 0.4$ (dashed lines) and $\alpha_p = 1$ (solid lines) were used. The tracks terminate near the end of central helium burning.

Paczynski, and Zimmerman 1973; Alcock and Paczynski 1978; Hellings and Vanbeveren 1981; Brunish and Truran 1982a). A comparison of six evolutionary tracks for schemes S and L in the case of our representative chemical composition is illustrated in Figure 4.

If a star initially becomes a red supergiant, its effective temperature depends somewhat on the details of the structure of the outer convective envelope (Fig. 5). More importantly, these details influence whether or not an evolutionary “blue loop” develops later on the H-R diagram. For example, we consider here the well-studied case of $30 M_{\odot}$. If $\alpha_p = 0.4$ is adopted, a blue loop formally develops, as shown on Figure 5. However, a recomputation of this evolutionary sequence with slightly different mass zoning and time steps is found to lead to complete suppression of the blue loop. If $\alpha_p = 1$ is used, no blue loop develops (Fig. 5). But by assuming a deeper penetration into the hydrogen-depleted layers by the outer convective envelope, a blue loop can easily be induced (Stothers and Chin 1981).

Mass loss, on the other hand, probably dominates the evolutionary history of a star for an initial mass greater than $\sim 30 M_{\odot}$. A large enough amount of mass loss will suppress the FCZ. However, the estimated uncertainties of the observed rates of quasi-steady mass loss are perhaps a factor of 2 (de Jager, Nieuwenhuijzen, and van der Hucht 1988), and this amount of uncertainty can mean the difference between a negligible loss of mass and a loss of the star’s entire

hydrogen envelope, in the case of the most massive stars of all (Chiosi and Maeder 1986). Observations of dust shells around very massive evolved stars indicate that these stars are subject also to episodes of sudden, heavy mass loss, with consequences that are still very uncertain from a theoretical viewpoint (Stothers and Chin 1979, 1983; Maeder 1983, 1985; Doom, De Greve, and de Loore 1986). Therefore, the problem of the post-main-sequence evolution of stars initially heavier than $\sim 30 M_{\odot}$ cannot be regarded yet as being close to a solution.

IV. CONCLUSION

The tables of evolutionary sequences presented here are homogeneous in regard to the basic input physics used and cover wide ranges of the “free” input parameters. However, these evolutionary sequences are not claimed to be the most physically realistic among all that have been published. That is a question beyond the scope of this paper. To afford readers a guide to other published work, we present Table 23, which refers only to papers that include tables of models for evolutionary sequences with at least three initial (mass, composition) combinations and $M_i/M_{\odot} \geq 10$, $Z_e > 0$, and modern Los Alamos opacities. Prescriptions used for mass loss and for convective core overshooting are generally different from those adopted here, and one paper included models with $M_i/M_{\odot} > 120$ (Maeder 1980), while five papers considered models with $Z_e < 0.02$ (Trimble, Paczynski, and

TABLE 23
SETS OF TABLES OF MODERN EVOLUTIONARY SEQUENCES OF MASSIVE STARS WITH $Z_e > 0$ PUBLISHED BY OTHER AUTHORS

Author and Date	X_e	Z_e	M_1 / M_\odot	N	Remarks
Ezer and Cameron 1967	0.739	0.021	10, 20, 50, 100	4	MS only; semiconvection
Robertson 1972	0.800, 0.708, 0.617, 0.602	0.021, 0.044	12, 15, 20	7	Semiconvection
Ziółkowski 1972	0.700	0.030	15, 30, 60	3	
Barbaro <i>et al.</i> 1973	0.700, 0.602, 0.500	0.020, 0.044	20	6	Semiconvection
Trimble, Paczyński, and Zimmerman 1973	0.700	0.001	10, 12, 30	3	
Alcock and Paczyński 1978	0.700	0.0004, 0.001, 0.003,			
Chiosi, Nasi, and Sreenivasan 1978	0.700	0.010, 0.030	10	5	Semiconvection
de Loore, De Greve, and Vanbeveren 1978a	0.700	0.020	20, 30, 40, 60, 80, 100	18	Mass loss; semiconvection
de Loore, De Greve, and Vanbeveren 1978b	0.700	0.030	20, 30, 40, 50, 60, 80, 100	21	MS only; mass loss
Chiosi, Nasi, and Bertelli 1979	0.700	0.030	50, 60, 80, 100	8	MS only; mass loss
Czerny 1979	0.700	0.030	20, 60, 100	6	MS only; mass loss; semi-convection
Maeder 1980	0.742, 0.700	0.008, 0.030	40, 60, 80, 100, 120	5	MS only; mass loss
Andriesse, Packet, and de Loore 1981	0.700	0.030	15, 30, 60, 85, 120, 170, 240	26	MS only; mass loss
Hellings and Vanbeveren 1981	0.760	0.003	40, 60, 100	3	MS only; mass loss
Maeder 1981a, b	0.700	0.030	20, 40, 60, 100	8	MS only; mass loss
Brunish and Truran 1982a	0.7198, 0.719, 0.710	0.0002, 0.001, 0.010	15, 30, 60	9	Mass loss
Brunish and Truran 1982b	0.700	0.020	15, 30, 40	18	Mass loss; semiconvection
Doom 1982a, b	0.700	0.030	10, 15, 20, 30, 35, 40, 60, 80, 100	6	Mass loss; semiconvection
Maeder 1983	0.730	0.020	60, 85, 120	9	MS only; mass loss; overshooting
Sreenivasan and Wilson 1985	0.700	0.030	40, 60, 80, 100	3	Mass loss
Xiong 1986	0.750	0.030	15, 30, 60	4	Mass loss; semiconvection
Maeder 1987	0.730	0.020	15, 20, 25, 40, 60	6	MS only; overshooting
Maeder and Meynet 1987	0.700	0.020	15, 20, 25, 40, 60, 85, 120	5	Mass loss
Maeder and Meynet 1988	0.700	0.020	12, 15, 20, 25, 40, 60, 85, 120	7	Mass loss; overshooting
				8	Mass loss; overshooting

NOTE.— N is the number of evolutionary sequences published in tabular form.

Zimmerman 1973; Alcock and Paczyński 1978; Maeder 1980; Hellings and Vanbeveren 1981; Brunish and Truran 1982a).

In their broadest aspects, the evolutionary tracks published by other workers for similar input parameters agree with ours, in particular for the main-sequence phase, although unresolved differences of detail remain (de Loore 1988). For the post-main-sequence phases, although the general trends discussed here are certainly valid since they have long been established by many investigations, absolute differences between the evolutionary tracks from different

authors can be quite large. This doubtless has to do with the sensitivities of both the initial location of stable core helium burning on the H-R diagram and the possible development (or nondevelopment) of a blue loop from the red supergiant region. Since mass loss, convective core overshooting, and semiconvection are treated differently in the different studies, comparisons may not be entirely valid. Observations, in any case, will be the ultimate arbiter, but the accuracy and abundance of observational data required probably exceed what are now available, even for main-sequence stars.

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